

PERSPECTIVES IN FOREST POLICY AND TRADE
FOR EASTERN BOLIVIA

By

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To my parents, Charles and Anne Merry.

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TABLE OF CONTENTS

	<u>page</u>
ACKNOWLEDGMENTS	iii
LIST OF TABLES	vi
LIST OF FIGURES	viii
ABSTRACT	ix
 CHAPTERS	
1 AN INTRODUCTION TO FORESTRY AND RANCHING IN EASTERN BOLIVIA	1
Introduction and Research Format	1
Introduction to Eastern Bolivia	2
Forestry in Eastern Bolivia	3
Ranching in Eastern Bolivia	10
The Cattle Herd of Eastern Bolivia	12
2 A STUDY OF LAND CONVERSION FROM FOREST TO PASTURE IN THE BOLIVIAN LOWLANDS	23
Introduction	23
Government Policy and Forest Management	26
Forestry and Cattle Production in the Lowlands	27
A Linear Programming Model to Analyze Land Conversion	30
Results	34
Regional Productivity and Land Conversion	36
Stumpage Values and Land Conversion	41
Forest Management Costs and Land Conversion	43
Land Use Taxes and Land Conversion	46
Conclusion	50
3 FACTORS AFFECTING BOLIVIAN MAHOGANY EXPORTS WITH POLICY IMPLICATIONS FOR THE FOREST SECTOR	53
Introduction	53
Model	57

Data	62
Results	64
Conclusions and Policy Implications	68
4 THE LAW OF ONE PRICE AND U. S. MAHOGANY IMPORTS FROM BOLIVIA AND BRAZIL	70
Introduction	70
Literature Review, and Testing of the Law of One Price	78
Testing the LOP for Mahogany Imports to the U. S. from Bolivia and Brazil	86
Results	90
Conclusion	92
5 CONCLUSION	95
REFERENCES	101
BIOGRAPHICAL SKETCH	108

LIST OF TABLES

<u>Table</u>	<u>page</u>
1.1 Logging by Department	4
1.2 Value of Forest Product Exports from Bolivia	7
1.3 Forest management Costs: 1,000 and 5,000 Hectares	9
1.4 Cattle Population in Santa Cruz by Province, 1992-1995	14
1.5 Schedule of Cattle Production Activities	17
1.6 Cattle Production Budgets for the Chiquitania	19
1.7 Transportation Costs for Cattle and Beef	22
2.1 Selected Wood Exports from Bolivia*, 1998, with Regional Species Distribution	29
2.2 Base Levels for Model Variables	33
2.3 Regional Variation for Selected Variables	35
2.4 Regional Comparison of Land Conversion to Pasture (3,000 Hectare Area)	40
2.5 Economies of Scale in Forest Inventory Preparation (\$US, 1995)	44
2.6 Costs of Sustainable Management on Private Forests of 1,000 and 5,000 Hectares	45
2.7 Land Tax Schedule for Livestock Ranches, 1996	48
2.8 General Land Conversion Impacts with Changes in the Land Use Taxes	48
2.9 Variations in Forest and Pasture Land Taxes: Their Effect on Land Conversion (5,000 hectares)	50
3.1. Data description and sources	60
3.2. Summary statistics for selected variables	63

3.3.	GMM Estimates of Mahogany Supply and Demand in Bolivia, 1977-1993	65
3.4	Partial Equilibrium Effects in Mahogany Supply and Demand	66
4.1	Historical Averages for Mahogany Exports to the U. S. from Selected Countries	74
4.2	Average Annual Price (\$/M3) for Mahogany Imports from Aggregated Regions	75
4.3	Average Annual Volume (M3) Imports from Aggregated Regions and Total Annual Imports of Mahogany into the U. S.	76
4.4	DF Results for Unit Roots for Bolivia and Brazil Mahogany Prices-1974-2000	91
4.5	EG Results for Testing Cointegration of Mahogany Prices Between Bolivia and Brazil-1974-2000	91
4.6	DF Results for Unit Roots for Bolivia and Brazil Mahogany Prices-1992-2000	91
4.7	EG Results for Testing Cointegration of Mahogany Prices Between Bolivia and Brazil-1992-2000	92
4.8	DF Results for Unit Roots for Bolivia and Brazil Mahogany Prices-Monthly,1992-2000	92

LIST OF FIGURES

<u>Figure</u>	<u>page</u>
1.1 Map of Bolivia	5
2.1 Geographical Site Descriptions for Five Regions in the Bolivian Lowlands	37
2.2 Percent Land Conversion by Initial Stumpage Volume and Prices	41
2.3 The Effect of Pasture Taxes on Land Conversion under Conditions of High and Low Management Costs	49
3.1 Mahogany exports from Bolivia, 1974-1993	56
4.1 Mahogany Imports from Brazil, 1974-2000	77
4.2 Mahogany Imports from Bolivia, 1974-2000	77
4.3 Mahogany Prices from Brazil and Bolivia, 1974-2000 (Unadjusted)-Bolivia with Marker	88
4.4 Bolivian Mahogany Prices, 1974-2000 (per M3) Unadjusted	88
4.5 Brazilian Mahogany Prices, 1974-2000 (per M3) Unadjusted	89
4.6 Mahogany Price Difference Between Brazil and Bolivia (Brazilian minus Bolivian Price)	89

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PERSPECTIVES IN LAND USE, THE TIMBER TRADE,
AND FOREST POLICY FOR EASTERN BOLIVIA

By

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Approximately 51 percent of Bolivia's 1,100,000 Km² is covered in forest. All of the tropical forest is located in the lowlands of Eastern Bolivia, which incorporates the Departments of Santa Cruz, Beni, Pando, and northern La Paz. For the past few years, change, brought on by new forest and land use laws, has been apparent. This dissertation broaches these changes with three studies under the umbrella of sustainable forestry. The first considers the land use tradeoff between sustainable forestry and cattle production. A linear programming model is developed to analyze the land conversion from sustainable forestry, as prescribed by the new legislation, to pasture. The second two examine aspects of the mahogany trade, a dominant product in Bolivian forestry. The first trade study is an econometric model of the supply and demand for Bolivian mahogany. The second trade study tests whether the law of one price holds between Bolivian and Brazilian mahogany using a cointegration technique. These separate

perspectives are linked within the overall issue of forest policy and trade in Eastern Bolivia.

Results from the study suggest that (1) the rate of land conversion to pasture will differ between regions and that some flexibility in the land use taxes, to adjust for this difference, is warranted; (2) under certain conditions, increasing profits in sustainable forestry can exacerbate land conversion to pasture; (3) policies which control the area under concession are not likely to affect the supply of mahogany—a more effective means of controlling mahogany supply would be pricing policies such as export taxes; and (4) the law of one price does not hold for U. S. mahogany imports from Brazil and Bolivia. This implies that the mahogany is differentiated by country of origin and that country-specific legislation plays an important role in the management of the mahogany resource.

CHAPTER 1

AN INTRODUCTION TO FORESTRY AND RANCHING IN EASTERN BOLIVIA

Introduction and Research Format

The main body of the dissertation comprises three chapters that are designed to be published as individual research papers. This, unfortunately, causes some replication of introductory material. The rest of the dissertation is designed in the following format. Chapter 2 is a study land use competition between sustainable forestry and cattle production. The objective of this chapter is to examine the new land use dynamics in the Lowlands created by the removal of forest concessions and the imposition of new land use taxes and planning requirements. An empirical model is developed to assess the rate of land conversion between these two important land use options in the Lowlands. The model is used to determine how land conversion will change when subject to regional productivity differences and to changes in net returns to sustainable forestry.

In Chapter 3 an empirical model is developed to quantify the factors that affect mahogany export supply and demand from Bolivia. Mahogany has been the single-most important resource of the Bolivian forestry sector, yet there has been no previous empirical study about its trade.

In Chapter 4 the Law of One Price (LOP) is tested for mahogany from Brazil and Bolivia. Because these two countries provide an average of 78 percent of the total US

imports, it is important to begin to understand the interaction of their markets and production.

Finally, although each chapter has an individual conclusion, Chapter 5 is used as an opportunity to summarize the contents and results of the whole work.

Introduction to Eastern Bolivia

Population growth, mineral resources, infrastructure, timber extraction, and the emergence of an industrial agricultural sector have all contributed to the extraordinary change in the Eastern Lowlands of Bolivia, a transformation which is likely to continue into the foreseeable future. Notable in this change has been the explosion of agricultural and forestry activity in the Santa Cruz. Current agricultural and forestry production now comprises 2 percent of Gross National Product and approximately 20 percent of Gross Departmental Product for Santa Cruz. For a nation whose modern economic history had been based on mineral extraction in the highlands, these figures represent an important diversification of the economic base.

Agriculture and forestry are now prominent factors in determining land use patterns in Santa Cruz. Of the total 36.5 million hectares that constitute the Department of Santa Cruz 5.4 million hectares have agricultural potential with varying degrees of production limitations and an additional 2.6 million has limited agricultural potential. Approximately 28 million hectares are suitable for either beef production and/or forestry. With only 750,000 hectares currently under agricultural production, and five to six million allocated to forest concessions, it would appear that there is capacity for growth in both agricultural and forestry sectors. Assuming that economic development is a desired

goal for the region, and to ensure that the land resource is at once productive and enduring, a balance between development and resource conservation must be realized.

Part of this dissertation is to review how recent developments in agricultural and forestry production may affect the interaction between forestry and cattle production and, as such, land use patterns in Eastern Bolivia. The dissertation also presents the first empirical analyses of the Bolivian trade in mahogany which is a vital component of determining change in the forest sector. The remainder of this introductory chapter serves to set the stage for the analyses, providing background information on the two sectors used in the empirical analysis.

Forestry in Eastern Bolivia

There are six identified forest ecozones throughout Bolivia (Lopez 1993). These are *Evergreen lowland forest* found principally in the Beni and Pando, to a lesser extent in Santa Cruz, Cochabamba, and La Paz. This formation is extensive (approximately 245 Km²) and is characterized by undulating alluvial plains lower than 500 meters above sea level (masl), annual rainfall 1,300 to 2,300 mm, and has a 2-3 month dry season. Moving south, the *Subtropical humid forest* in Santa Cruz is the most important commercial zone, recording an average of 60 percent of official total log production, 80 percent of mahogany exports from 1980-1993, and accounting for a total export value of \$44.5 million in 1994 (Camara Nacional Forestal [CNF] 1995). This zone is characterized by a diverse forest with more than 100 potential wood species. It is located at 300-400 masl and has an annual rainfall of 1,200 to 2,000mm. The *Semi-humid low forest* is found in the Chiquitania region of Nuflo Chavez and Velasco provinces. Annual rainfall for this

zone is 900 to 1,200mm and the topography is fairly flat at between 350-400 masl. The *Semi-humid mountainous forest* extends south, is less productive, and reaches as high as 2000 masl. The *Semi-arid low forest* is found in the Southwest of the forested region and has lower forests. Rainfall varies between 500 and 1000mm and altitude ranges from 350 to 1000 masl. The *Yungas forest* is found in the northwest of the forest region, in the valleys of Cochabamba and la Paz (Lopez 1993).

There are conflicting claims of forest productivity with a range of estimates from 12 to 18 million hectares of productive forest (Mancilla 1996, International Tropical Timber Organization [ITTO] 1996). Santa Cruz has been the most important area of log extraction, recording approximately 54 percent of total log extraction in 1995 (Table 1.1). As commercial stocks become depleted, however, more attention has been given to other areas. This was demonstrated by the recent granting of 19 new concessions in the Pando, a region where there had previously been little forest activity. Figure 1.1 shows a map of Bolivia.

Table 1.1 Logging by Department, 1995

Department	Volume of logs (M3)	Percent
Santa Cruz	240.54	53.61
Cochabamba	91.88	20.48
La Paz	73.21	16.32
Beni	39.07	8.71
Other Departments	4.00	0.89
Total	448.70	100.00

Source: CNF(1995)



Figure 1.1 Map of Bolivia

Export Markets

The export market is estimated to be 70 percent of the total market for Bolivian wood. Wood exports were valued at 82 million \$US in 1996, up from 49 million in 1990. The driving force for the past twenty years in the forestry sector has been the selective logging and export of mahogany. Although unsubstantiated, it is accepted that mahogany stocks are in serious decline, and with continued extraction will become commercially extinct (Stolz and Quevedo 1993).

With the decline of mahogany stocks, there is now a concerted effort to improve the per hectare value of forest land by encouraging the extraction and export of lesser known species. To date, relatively few have been exported in any significant volume, with Roble (*Amburana caerensis*) and Cedro (*Cedrela* sp.) as two notable exceptions. Indeed, the roble export volume in 1994, at 35,000 M3, was greater than mahogany at 30,000 M3, however, the mahogany value remained greater at \$US14,309 a million vs. \$US10,916 for roble. Currently Ochoo (*Hura Crepitans*) is also finding wider appeal and in the export market in addition to being a mainstay in the domestic market. The importance of these alternative products becomes apparent when examining the changes in export volumes and diversity. The most prolific of the sawn wood exports for 1994 include the following species: Yesquero (*Carinaiara estrellensis*), Morado (*Peltogyne* sp.), Tarara (*Centrolobium* sp.), Sirari (*Ormosia* sp.), Tajibo (*Tabebuia* sp.), Plumero (*Vochysia lanceolata*), Cambara (*Erismia uncinatum*), Palo Maria (*Calophyllum brasiliense*), Paquio (*Hymenea stilbocarpa*). The diversity of species now exported in the form of sawn wood has increased dramatically from only eight species in 1985 to twenty-four species in 1994. Of the sawn wood exports, principal destinations for forest

products during 1994 were Argentina, which received 58.24 percent of the total export value, the U. S. with 17.26 percent, Uruguay with 8.2 percent, Mexico with 5.87 percent, Chile with 2.16 percent, and Japan with 1.87 percent. In addition there has been some success with the introduction of value-added processing. Table 1.2 shows the market share of sawn wood and processed wood for the period between 1990 and 1996.

Table 1.2 Value of Forest Product Exports from Bolivia

Product Group	1990	1991	1992	1993	1994	1995	1996
	(millions of dollars)						
Sawnwood	36.4	41.6	41.2	44.5	70.8	63.2	64.6
Processed Products	12.5	7.4	8.8	8.8	18.6	15.6	17.8
TOTAL	48.9	49	50	53.3	89.4	78.8	82.4

Note: Processed products include sleepers, veneer, plywood, flooring, moldings, and others.

Source: CNF (1997)

Domestic Markets

The domestic wood market is characterized by the extensive use of low grade timber. However, data on the market is unreliable at best. A recent International Tropical Timber Organization (ITTO 1996) estimate put the volume at around 324,000 M3. This market is primarily supplied by wood that comes from small farmers and colonists clearing land for agriculture, or wood that is not of exportable quality from the large sawmills.

The process of domestic timber supply is from small farms to small sawmill owners. The sawmill operators look for instances of new clearing and extract the timber immediately before the process begins. This provides a service for the farmer by

removing the biggest and most cumbersome trees. The timber merchants also create rudimentary roads when they extract the logs, which provide access for the farmer. The stumpage value for these trees, regardless of size and quality, is very low, often as low as \$5 to \$10 per tree. The low stumpage value is a function of a saturated market, an abundance of the resource, and a need for the farmer to remove the tree in order to farm. Most of this activity takes place on land that is being cleared along new roads. Principally along the new road to Cochabamba in provinces of Sara and Ichillo.

Timber Prices

A survey of timber prices (Cordova 1997) reports stumpage prices for 24 species in various parts of the Chiquitanía and Guarayos of Santa Cruz, plus the integrated area of north Santa Cruz, and the river port of Puerto Villaroel in the Chapare. All but five species range in price from \$7 to \$12 per tree. Five species reached higher levels: Almendrillo at 17, Verdolago at 19, Cedro at 23, Roble at 29 and Mahogany was quoted at \$46 per tree. There are about 2 cubic meters of stumpage in each tree.

Forest Management Costs

Table 1.3 presents an estimate of sustainable forest management costs. Calculations are based on time requirements and prevailing salary levels, as little data is available from actual experiences of landowners. Total costs are then averaged over the area of the entire forest production unit. With higher relative fixed costs for planning, the costs of sustainable management practices appears to be much higher per hectare for smaller areas- \$6.55 per hectare for a 1,000 hectare forest unit versus just over \$2.73 per hectare for a 5,000 hectare unit.

Table 1.3 Forest management Costs: 1,000 and 5,000 Hectares

Costs	1000 hectares		5000 hectares	
	Fixed	Variable	Fixed	Variable
Planning				
Preparation of management plan and inventory	2510		3963	
Preparation of annual operating plan and census		2250		4450
Production				
Road building	1800		3600	
Supervision		2691		5336
Forest tax		50		250
Other				
Marketing		700		2100
Total Costs	4310	5691	7563	12136
Depreciation of fixed costs		862		1513
Average annual cost per hectare		6.55		2.73

Source: BOLFOR (1996)

Small landowners who intend to incorporate forestry into their land use plans, whether a concession or a private landowner, must now prepare a management plan, take inventory, and prepare an annual operating plan. The combined cost of these plans could become an area of concern in the promotion of sustainable use on smaller private land holdings. The costs, at \$2,510 for 1,000 hectares and \$3,963 for 5,000 hectares, for the management plans and inventory are high. The operating plans are prepared annually and involve a commercial census, material purchase and the preparation of the plan. Table 1.3 shows the costs of preparing annual operating plans to be \$2,250 for 1,000 hectares and \$4,450 for 5,000 hectares.

Log and Lumber Transportation Costs

Logs are usually transported over relatively short distances to sawmills. This is especially true in the case of lumber companies that can locate sawmills in or near concessions, allowing transport of logs within only about 30 kilometers. General surveys of loggers and sawmill operators determined an average distance of 52 kilometers in 1997 (Cordova 1997). In a few cases, logs are transported much larger distances. Transport costs decrease with distance, ranging from less than \$0.10 for distances of more than 100 kilometers to more than \$0.20 for distances less than 50 kilometers.

Lumber is transported from sawmills to local market and processing centers- mainly Santa Cruz, La Paz and Cochabamba- with distances between 300 and 1400 kilometers. Infrastructure, even from sawmills to major cities, consists mostly of dirt roads useable only during dry weather. Average cost of transport by truck is close to \$0.065 per kilometer for a cubic meter of lumber while the cost by river boat is close to \$0.028. In addition export products incur an additional transportation cost from Santa Cruz to the port at Arica of \$74 per metric ton which translates into approximately \$60 per cubic meter.

Ranching in Eastern Bolivia

For the past two decades there has been extensive debate on the interaction between ranching and tropical forests in Latin America. The primary concern has been deforestation to provide land for pasture and cattle production. The literature has focused, with good reason, on two geographic regions: Central America, where the concern was that forest were being destroyed to produce cheap beef for the U. S. market,¹

¹The term "hamburger connection" was coined by Meyers (1981) to describe this phenomenon.

and Brazil, where vast areas of the Amazon were opened up for cattle production. Although these two areas have received much of the attention, the interaction of cattle production and forests is apparent in many countries of Latin America, including Bolivia.

The increase of land allocated to cattle production at the expense of natural forests is the result of several interactive factors (Kaimowitz 1996) that include:

- land tenure policies,
- extensive cattle production systems (Serrao and Toledo 1992, 1993),
- low timber values (Kishor and Constantino 1993),
- production characteristics of cattle (Hecht 1992),
- favorable markets and prices (Meyers 1981, Nations and Komer 1983),
- government subsidies for livestock credit and road construction (Mahar 1988, Binswanger 1991).

Of these characteristics, the first four are applicable to Bolivia. Historically, land tenure has been established by clearing. As with many other countries, this has led to uneconomic exploitation and destruction of the forest resource. This situation has changed however with the inception of the new agricultural law which described forestry as productive use. This simply states that forestry is a productive use, sufficient to establish tenure.

The second factor, slow technological change, has been a truism of cattle production in Bolivia. Production is mostly extensive and Bolivia still has not controlled foot and mouth disease. There is, however, a substantial herd located in the area immediately surrounding the city of Santa Cruz, that is under more intensive management and these techniques may transfer to other producers in the future. Third, Bolivia has not

actively had policies that depress timber values, but legislation that differentiated between subsoil resources, the soil resources, and above-soil resources has served to make timber extraction difficult for private landowners. The legislation stated that subsoil resources (minerals) and above-soil resources (forests) belonged to the state and were allocated by extraction permits. Soil resources, on the other hand, were allowed to be held in private ownership. The confusion arose regarding the extraction of timber from private land. To remedy this predicament the current legislation allows extraction of timber from private lands. Fourth, in Bolivia the characteristics of cattle production such as low labor and supervision inputs, transportability, limited risk, prestige, limited inputs, and biological and economic flexibility all play a role.

The final two explanations are not applicable to the growth of cattle production in Bolivia. That is to say, these factors have not been part of the economic environment and therefore have not played a significant role. The market for Bolivian beef is limited to domestic consumption and finally, there has been no subsidized credit to cattle production nor have there been substantial improvements in infrastructure.

The rest of this section will illuminate some of the constraints and potential in the Bolivian cattle sector by addressing the following: the cattle herd, markets and prices; production activities, a timetable and budget; and, finally, grasses, land clearing and fencing.

The Cattle Herd of Eastern Bolivia

Cattle ranches in Eastern Bolivia are usually extensive operations, characterized by low input and management costs. Stocking rates and production efficiency have been notoriously low, and there have been few technological changes until very recently.

Regardless, the cattle sub-sector contributed 7.5 percent to the 1998 regional value product, with a total of 56.5 million dollars. Land in the Bolivian lowlands is suitable for cattle production—a fact confirmed by the land use plan for the extensive Santa Cruz Department, which shows 23.6 million hectares (64 percent), of a Department total of 37 million to be suitable for cattle ranching in one form or another.

The current Bolivian cattle population is approximately six million head, up 9 percent from the 1990 population of 5.5 million. Of the six million head, 2.7 million are in the Beni and 1.5 million in Santa Cruz, such that these two departments alone comprise 70 percent of the total herd. In the center of the Department of the Beni, livestock range on vast natural grasslands. This region is subject to severe seasonal flooding in summer months (November through March) and to dry conditions prevailing in winter. Ranching in this region is extensive, but the natural grasslands still permit cattle production at low cost. Ironically, the major production constraint in this region is not the ability to find feed in the dry season, but rather to find high, dry land in the wet season.

The Department of Santa Cruz covers more than one third of the country's entire territory, and lies at the center of the lowlands, ranging from humid areas to the north bordering the Beni to the dry Chaco in the south. Table 1.4 shows the distribution of the cattle herd by province in the Department. The three principal regions of cattle production within Santa Cruz depict the variations found throughout the east. The first is the expansion zone surrounding the city of Santa Cruz where intensive beef cattle and dairy production are developing alongside a thriving agricultural industry based on sugar cane, rice, soybean, sunflower, sorghum, wheat and other field crops. About a third of the Department's cattle population can be found here under relatively intensive

management on improved grasses. In many cases, land that was originally cleared for agricultural production has reverted to pasture. In recent years, it has become more common to bring young steers into cultivated pastures near Santa Cruz for fattening before final sale. With marginal agricultural land is available for productive establishment of pasture and the burgeoning urban market of Santa Cruz providing a substantial demand, it is expected that the trend toward cattle production will continue to expand in this area.

Table 1.4 Cattle Population in Santa Cruz by Province, 1992-1995

Province	1992	1993	1994	1995
	(head)			
Andrés Ibanéz	126,916	130,723	134,645	138,685
Warnes	68,403	70,455	72,569	74,746
Obispo Santiestevan	43,516	44,821	46,166	47,551
Sara	86,222	88,809	91,473	94,217
Ichillo	48,722	50,184	51,689	53,240
Florida	76,123	78,407	80,759	83,182
Vallegrande	108,386	111,638	114,987	118,436
M.M. Caballero	40,584	41,802	43,056	44,347
Cordillera	239,134	246,308	253,697	261,308
Chiquitos	110,360	113,671	117,081	120,593
Núfelo de Chavez	117,686	121,217	124,853	128,599
Velasco	151,568	156,115	160,798	165,622
Angel Sandoval	181,532	186,978	192,587	198,365
Germán Busch	53,158	54,753	56,395	58,087
Guarayos	39,335	40,515	41,731	42,982
Total	1,491,645	1,536,396	1,582,486	1,629,960

Source: Camara Agropecuaria del Oriente (CAO) 1996

The second production region is the Chiquitanía, which cuts a diagonal swath from top left to bottom right through eastern Santa Cruz. Designated as mostly joint,

sustainable forest management and limited cattle production, this area holds about 40 percent of the cattle population of Santa Cruz. Extensive ranching on wooded savannas characterizes cattle production in much of the area, and the interaction between forests and cattle has been underway for more than two hundred years. Cattle production is increasing in this region, with the gradual clearing of forests. Most soils are not apt for agricultural production, but infrastructure improvements have made the Santa Cruz market more accessible for cattle ranchers. Improved grasses are a necessity for cattle production in this region as domestic grasses are of poor quality.

The final area of cattle production is the Chaco where production is practiced on an extensive scale, with as much as 15-20 hectares needed to maintain a single animal unit. This harsh, dry region holds approximately 20 percent of the Departmental herd, and much of this region is described in the Departmental land use plan as useful only for extensive cattle production, with some forestry. The Bolivian Chaco region continues further south through the Departments of Chuquisaca and Tarija to the borders with Paraguay and Argentina.

Beef Markets and Prices

Limitations in the export markets are created by high transportation costs and the continued incidence of hoof-and-mouth disease. Until a few years ago, much of the meat supply reaching the city of La Paz was transported by air from rustic slaughtering operations at ranches in the Beni. Cattle are still shipped by river in the Beni and then trucked to market in Cochabamba. Even transportation to the Santa Cruz market is difficult from many areas. The only three commercial abattoirs are located within the city

of Santa Cruz, and therefore animals are transported live from connecting regions. Efforts to export to points east and south (Brazil and Argentina) are stymied by lower prices and higher product quality in those regions.

The second export constraint is hoof-and-mouth disease, which creates an export barrier to countries or areas free of this disease. There is an active campaign to eliminate hoof-and-mouth disease from certain areas in the Bolivian lowlands. Meanwhile, the severe constraints on exports ensure that the domestic market for beef is of paramount importance to producers.

Local prices are cited in dollars per kilogram on the hook and are about \$1.50 per kilogram with little price differential given for higher quality beef. Animals are usually grown out on ranches and are marketed at full size between three and four years of age at about 350 to 400 kilograms live weight. National consumption is very low, only about 18 kilograms per capita annually.

Production Activities, Timetable and Budgets

Production activity for cattle is aligned with the seasons. Calves are timed to be born in August, immediately before the rains, and to be weaned in April/May at 7-8 months old. All associated activity is based around this cycle. Table 1.5 shows the production timetable for the experimental ranch "El Salvador" located in the Chaco. Within this timetable, strict attention should be paid to pest and disease management under the difficult conditions of the Bolivian lowlands. However, these practices are often neglected, to the detriment of production efficiency. The following is a brief description of the pest and diseases prevalent in the Bolivian Lowlands and, indeed, throughout much of Latin America.

Table 1.5 Schedule of Cattle Production Activities

Affliction and control	Month	J	F	M	A	M	J	J	A	S	O	N	D
Foot and Mouth—once/yr, all herd													
Rabies—once/yr, all herd													
Blood infections— all herd													
Gangrene—all herd													
Neonatal diarrhea—birthing months													
Brucellosis— all females 1-2 years old													
Internal (ecto) parasites – injection													
External (endo) parasites – all year													
Trichomonas, Leptospirosis, and Baloneprostitis—in bulls													
Mineral salts—during rainy season													
Neumoenteritis—alcohol at birth													

Source: FEGASACRUZ: Manual de Ganadería del Chaco, 1994.

At birth, calves should receive injections against endo/ecto parasites. Worming is then done about every three months thereafter until calves attain about 300 kilograms. Cows and bulls should be wormed every six months at the beginning and end of the rainy season. External parasites such as ticks, mosca del cuerno, and borbor *Dermatobia homini* are controlled by spraying with insecticide. Regular rotation of pastures also helps in tick control. Calves should get three vaccines at three months old—against Black leg (gangrene), Malignant edoema, and Hemorrhagic septicaemia. Female calves receive an additional vaccine at 3-7 months against brucellosis. All animals are vaccinated against rabies once a year and hoof-and-mouth disease once a year. All females are vaccinated once a year against Leptospirosis.

Total production costs, on small, medium, and large ranches, are estimated to be around \$1.13/kg, \$0.72/kg, and \$0.61/kg, respectively (Table 1.6). Fixed costs of production, which include administrative costs and depreciation costs, range from 60 percent for small, 56 percent for medium, to 50 percent for large producers.

Land Clearing for Pasture

There are several methods of land clearing, and the appropriate one will vary according to forest type and operator preference. For the lower, sparse, forest typical of much of the Chiquitania the choice is often chain clearing which consists of dragging a large chain between two bulldozers. At around \$200 per hectare this is a very cost effective method for low forests. One month after clearing the land is burnt, then seeded. Four months later, the grass will be dropping seed and cattle must be allowed on. The land is burnt again in the second and third years after which time the field should be effectively grassed. Because of the remaining stumps and half-burnt logs, mechanical control of brush and weeds is not feasible for many years.

With taller forests chain clearing is less feasible. Instead, bulldozers push trees and brush into windrows. The windrows consist of piles of brush to be burnt and the area is eventually grassed. Live forest corridors are left standing for windbreaks. This method, typical of that used with mechanized farming operations, is much more expensive than chain clearing but has the advantage of allowing mechanical control of weeds. Clearing costs can range between \$300 and \$550 per hectare, depending on the density of the forest, the remoteness of the region, and the size of the area to be cleared.

Table 1.6 Cattle Production Budgets for the Chiquitanía (San Ignacio–San Jose de Chiquitos)

Description	Small		Medium		Large	
Hectares	500 ha.		1,000 ha.		2,500 ha.	
Number of cows	250 cows		610 cows		1,200 cows	
Beef production	13,812.5 kg		33,702.5 kg.		66,300.0 kg.	
Cost description	\$ total	\$/kg.	\$ total	\$/kg.	\$ total	\$/kg.
Fixed costs	9,280	0.67	13,751	0.41	20,492	0.31
Depreciation	2,927	0.21	4,568	0.14	7,776	0.12
Administrative	6,353	0.46	9,183	0.27	12,716	0.19
Variable costs	6,292	0.46	10,660	0.32	19,951	0.30
Labor	2,161	0.16	2,165	0.06	3,829	0.06
Replacement animals	1,080	0.08	1,880	0.06	3,480	0.05
Health	575	0.04	1,331	0.04	2,570	0.04
Miscellaneous	846	0.06	1,974	0.06	3792	0.06
Sales/marketing	1,230	0.09	2,910	0.09	5,880	0.09
Technical assistance	400	0.03	400	0.01	400	0.01
Total production costs	15,572	1.13	24,412	0.72	40,444	0.61

Notes: Totals may not add due to rounding.

Source: CAO, 1996.

Land clearing requires the presentation and approval of an individual property land use plan and land clearing plan. Associated harvest of timber requires issuance of certificates of forest origin with payment of the area and volume-based taxes. The area tax or patent is currently set at \$15/hectare. The volume tax is computed at 30 percent of the value of timber at the land clearing site, according to a price list established by the Forest Superintendency. The landowner pays 15 percent of the value and the buyer of the timber another 15 percent. The price list applied by the Forest Superintendency for 1998

seems to reflect international timber prices less extraction and milling costs, which are several times higher than the amounts paid by local sawmills. Therefore, timber will be extracted from land clearing sites only in cases where the landowner is able to find interested lumber industries with capacity and access to international markets. Otherwise, the timber will be burnt off, a practice common in the Bolivian lowlands.

Fencing is estimated to run about \$376 per kilometer, assuming the terrain has already been cleaned when the land was cleared, and that posts are available on the property. Wire in 500 meter rolls requires eight rolls/kilometer when using four strands stapled to posts. With pastures of 50 hectares, the average cost of fencing per hectare comes to about \$21. Establishment of pasture requires approximately another \$40 for seed and \$20 for seeding.

In areas closer to markets, timber might be sold before burning, but local markets for common species used in construction are limited. Of the wood products used on-farm, by far the most important is the use of trees as fence posts. The logs are quartered, and depending on the size of the trunk will give anywhere from four to 10 posts per tree. Large posts are placed every 100 meters at 75 cm deep, and smaller ones every 5 meters at 60 cm deep. In this manner, 200 posts are needed per kilometer. The most popular species are very hard woods such as Cuchi (*Astronium urundurueva*).

Grasses

With the exception of the Beni plains, improved grasses are an important component of cattle ranching in much of the lowlands. In Santa Cruz, a total of 61,090 hectares has been planted to date (CAO 1997). Although there have been substantial

reports of declining pasture productivity in pasture created from tropical forests in Brazil, in most of the areas of Bolivia, it is accepted that grasslands can remain productive over long periods of time and, in fact, suffer more from problems of weed infestation rather than declines in soil productivity (Killeen 1991).

The most popular grasses are of the genus *Brachiaria*. *Brachiaria decumbens* performs best on well-drained soils and is considered by some to be the best all-around grass for much of the Bolivian lowlands because of its ability to resist trampling and provide forage during the dry season. *Brachiaria brisantha* is also used, but does substantially worse where drainage is limited. *Brachiaria humidicola* will tolerate both well-drained and poorly-drained soils and can survive in areas of standing water for long periods. It is also tolerant of dry conditions as are the other two *Brachiarias*. However, it does not have as high a nutritional value as the other two and is therefore good for breeding and growing, but not for fattening. *Brachiaria radicans* performs well in areas subject to flooding, and will tolerate dry conditions, but must be planted by stolon, rather than seed, which is labor intensive. Other *Brachiaria* species which are becoming commercially available are *Brachiaria dictyoniana* and *Brachiaria ruziziensis*.

Another popular grass is Yaraguá (*Hyparrhenia rufa*), which is especially predominant in the Chiquitania. It is palatable when young, and very vigorous on well drained land, such that it will tolerate poor land if drainage is adequate. It does not tolerate dry conditions and if not properly managed can become lignified. Finally, Guinea grass (*Panicum maximum*) and assorted improvements (Tanzania, Tobiata, Centenario) are thought to be among the best fattening grasses in South America. They

need well-drained soil but do not do well in dry conditions. These grasses can often be seen in cut-and-carry operations for breeding stock.

Cattle and Beef Transportation

Most of the beef in Bolivia is transported live, either by herding, truck, rail or river. Shrinkage, or weight loss during transport, is an important factor with these kinds of transport. Only recently, ranchers in the La Paz-Beni region have begun slaughtering locally and shipping beef sides to La Paz in refrigerated trucks. Table 1.7 shows some estimated transportation costs for selected regions.

Table 1.7 Transportation Costs for Cattle and Beef

	Gran Chaco	Chiquitania	Guarayos	Bajo Paraguá	La Paz Beni	Pando
	(\$US per head)					
Herd/truck	8.00	8.00		8.00	8.00	8.00
Rail		16.22				
Truck	36.36		25.00	52.50		52.50
Refrigerated truck					34.48	34.48
Truck to Market		5.00				
Federations	2.91	2.91	2.91	2.91	2.91	2.91
Municipal Tax	7.27	7.27	7.27	7.27	7.27	7.27
TOTAL	54.55	39.40	35.18	70.68	55.66	105.16

Source: CAO (1996)

CHAPTER 2

A STUDY OF LAND CONVERSION FROM FOREST TO PASTURE IN THE BOLIVIAN LOWLANDS

Introduction

Enactment of new forest legislation in 1996¹ in Bolivia, together with a new agricultural law,² has had the dramatic effect of reducing the area under forest concessions from 20 million hectares to about 6 million. But, whereas forestry activity could previously be undertaken only on forest concessions, the new legislation allows for forest management on private lands. Productive use of the forest, however, on both private and concession lands, now requires formal management planning and is subject to a uniform annual tax per hectare.³

Most of the former concessions, now returned to the state, were located in land-use zones designated for combined cattle and forestry production. It follows that a private landowner who gains control of that land will have either sustainable forestry or cattle production as the two primary land-use options. What is not clear, however, is whether the new legislation will have an unintended side-effect of encouraging land conversion as has happened in other regions of Latin America.

¹Nueva Ley Forestal, Ley Numero 1700, del 12 de Julio de 1996.

²The Ley de Servicio Nacional de Reforma Agraria, Ley No. 1715, 1997.

³On private lands, however, the tax is on the area harvested rather than the total area.

For the past two decades, there has been extensive debate on the interaction between cattle production and tropical forestry in Latin America, the primary concern of which has been deforestation to provide land for pasture. The increase of land allocated to cattle production at the expense of natural forests is said to be the result of several factors such as land tenure policies, extensive beef production systems, low timber values, production characteristics of cattle, markets and prices favorable to beef production, government subsidies for livestock credit, and road construction (Meyers 1981; Nations and Komer 1983; Mahar 1988; Binswanger 1991; Hecht 1992; Serrao and Toledo 1992, 1993; Kishor and Constantino 1993; Kaimowitz 1996). The literature has focused, with good reason, on two geographic regions: Central America, where the concern was that forests were being destroyed to produce cheap beef for the U. S. market (DeWalt 1982; Endelman 1985; Browder 1988; Graciela 1989), and Brazil, where vast areas of the Amazon were cleared for as a result of government subsidies to expansion (Hecht et al. 1988; Moran 1993; Barbier et al. 1994; Mattos and Uhl 1994; Arima and Uhl 1997; Faminow 1997).

It has been suggested that this land conversion was possible due to the forestry management practices of the time, which were primarily high grading—the extraction of only the best quality timber—and perverse production incentives for cattle. Now that the incentives for cattle production have diminished the “playing fields” have been somewhat leveled. In addition, it has been suggested that if the forests are managed in a sustainable manner, a greater number of timber species can be extracted, the marginal benefits per hectare will increase, and less land will be converted to pasture.

The objective of this chapter is to examine the new land use dynamics in the Bolivian Lowlands created by the removal of forest concessions and the imposition of new land use taxes and land use planning requirements. In this paper we develop a model to examine land conversion from sustainable forestry to pasture for cattle production. On a homogenous–single quality class–land area we address how conversion will change subject to changes in regional productivity and net returns per hectare (stumpage values) of sustainable forestry.

The simulation results clearly indicate that two regions of the Lowlands, the Chiquitania and Guarayos, are higher risk areas, and will likely suffer the most conversion from forest to pasture. All of the other regions–the Andean Foothills, Paraguá, and Pando–appear, under current conditions, to be in little risk of major land conversion within the next 20 years; due both to high forest productivity as well as poor cattle production conditions. The results also suggest that in many productivity scenarios, income from forestry releases a capital constraint and that, to a point, increasing per hectare returns to sustainable forestry can serve to exacerbate land conversion to pasture.

The rest of the paper is as follows: a brief overview of government policies associated with forest resource management; an introduction to forestry and cattle production in the Lowlands; a description of the model for the empirical analysis; an overview of the five regions identified throughout the Lowlands that will be used to compare regional susceptibility; and finally, a review of the results and a conclusion.

Government Policy and Forest Management

In developing nations with large forest resources the attraction to harvest that resource is inevitable. The main concern, however, is not that the forest resource is harvested but that the rent generated from that resource be captured by the government.

Three common options that governments have as policy tools for rent capture are the fully differentiated royalty, the flat rate or ad valorem royalty, and the uniform fixed royalty (Repetto 1987, Vincent 1990, Barbier 1991, Binswanger 1991, Hyde and Sedjo 1992, Deacon 1994). The fully differentiated royalty distinguishes among tree species, tree quality, land quality and access class and is intended to capture all possible rent between the market price and the marginal cost curve. The unavoidable problem associated with this form of royalty is the level of information and institutional support required for it to be effective.

The flat rate or ad valorem royalty are percentage charges on net revenues. There is no change in the level or quality of harvest rather the returns to the operator are simply decreased by the percentage of the royalty. Uniform fixed royalties are flat fees per unit of harvest (also area fees). These may not be effective because if the elasticity of harvest volume with respect to the uniform fixed royalty is greater than one then increasing the fixed royalty will in fact decrease government revenues (Hyde and Sedjo 1992).

Other options for government control of the forest resource can take the form of lump-sum bidding, or performance bonds. The recommendation given by Hyde and Sedjo (1992) for capturing the rent, including institutional and environmental costs, is with lump-sum bidding where concessionaires bid competitively for the right to harvest the resource or a combination of fixed royalty and competitive bidding. These would still

not preclude the need for information to be made available to the forest ministry. With forest performance bonds the government will essentially lease out the forest to the highest bidder but with stipulations on environmental management and performance indicators.

All of the royalty forms mentioned above are not without merit. It is, however, important to consider the practical side of forest concession management under the normal budget constraints of a forest ministry in the developing world. And it is here that the simpler forms, such as the area and the ad valorem tax, shine.

Forestry and Cattle Production in the Lowlands

Although Central America and Brazil have received much of the attention, the interaction between tropical forestry and cattle production is apparent in many countries of Latin America, including Bolivia. Indeed, cattle production has been part of the land use mosaic in the Bolivian lowlands for centuries and will undoubtedly remain so for the foreseeable future (Killeen 1991). The passage of new forest legislation in 1996, however, has changed the face of the forest industry and in doing so may also affect the cattle industry, and the potential for land conversion.

Approximately 51 percent of Bolivia's 1,100,000 Km² is covered in forest (Lopez 1993). The Department of Santa Cruz has long been the most important Department in the forest sector, recording an average of 60 percent of official total log production and 80 percent of mahogany exports during the period 1980-1993, and accounting for a total export value of 44.5 million dollars in 1994 (CNF 1995). Of a total 36.5 million hectares

in the Department, approximately 18 million (49 percent) are described as having regular, high, or very high forestry potential.

The Bolivian forest sector, however, is in the midst of change. Nineteen new concessions have been allocated in the far northern Department of Pando. And, with mahogany stocks in the decline (Stolz and Quevedo 1993), there has been a concerted effort to change, from selective harvest techniques, to sustainable forestry management that relies on lesser-known (and lesser-valued) species. Indeed, Cedro (*Cedrela fissilis*) has become the principal export wood in terms of both volume and value (Table 2.1). Given the new land use regulations, forest land now under the domain of the SF must be managed in a sustainable fashion, and therefore, in an effort to examine the possible impact of the new forest legislation on land use, this paper compares sustainable forest production (including forest management planning and tax costs) to the most likely alternative use—cattle production.

Except for the area immediately surrounding the City of Santa Cruz, cattle production throughout the Bolivian Lowlands is an extensive operation. The current Bolivian cattle population is approximately six million head, an increase of nine percent from the 1990 population. Of the six million head, 2.7 million are to be found on the vast natural grasslands of the Beni and 1.5 million in Santa Cruz, such that these two Departments alone comprise 70 percent of the total herd. Many areas of the Bolivian Lowlands, including those once in concession, are suitable for cattle production or a combination of forestry and cattle production. For example, in the department of Santa Cruz, 64 percent of the land is suitable for cattle production in one form or another.

Table 2.1 Selected Wood Exports from Bolivia^a, 1998, with Regional Species Distribution

Species	Scientific Name	Vol. (M3)	Value (\$US)	CH	GU	PG	AF	PA
Cedro	<i>Cedrela fisilis</i>	36,916	21,207,031	X	X	X	X	X
Mara (mahogany)	<i>Sweitenia macrophylla</i>	21,914	18,020,299		X	X	X	X
Roble	<i>Amburana cearensis</i>	21,037	14,580,969	X				X
Yesquero	<i>Cariniana estrellensis</i>	5,279	3,604,857	X	X	X	X	X
Lenga	<i>Nothofagus pumilio</i>	232	2,385,986		X		X	X
Palo María	<i>Calophyllum brasiliense</i>	2,735	2,309,137				X	X
Mara Macho	<i>Terminalia amazonia</i>	1,440	2,278,468		X	X	X	X
Ochoó	<i>Hura crepitans</i>	2,472	2,258,255		X	X	X	X
Morado	<i>Machaerium scleroxylon</i>	1,079	1,414,498	X				
Bibosi	<i>Ficus</i> sp.	1,379	1,365,653		X	X	X	X
Cambará	<i>Erismacalcaratum</i>	1,951	936,016			X	X	X
Paquió	<i>Hymenaea coubaril</i>	418	441,109	X	X	X	X	X
Tarara	<i>Centrolobium microchaete</i>	575	428,781	X	X			
Sirari	<i>Ormosia coarctata</i>	490	347,764	X				
Tajibo	<i>Tabebuia heptaphylla</i>	483	220,405	X	X	X	X	X
Almendrillo	<i>Dipteryx alata</i>	153	176,956				X	X
Quina	<i>Cinchona calisaya</i>	465	157,239				X	X

Species	Scientific Name	Vol. (M3)	Value (\$US)	CH	GU	PG	AF	PA
Plumero	<i>Vochysia lanceolata</i>	346	141,355		X		X	
Cuta	<i>Phyllostylon rhamnoides</i>	120	138,411	X				
Ajunao	<i>Pterogyne nitens</i>	204	104,127	X				
Soto	<i>Schinopsis brasiliensis</i>	283	81,500	X				X
Picana Negra	<i>Cordia alliodora</i>	82	66,167	X	X	X	X	X
Quina Quina	<i>Cinchona officinalis</i>	36	46,021				X	X
Jichituriqui	<i>Aspidosperma cylindrocarpon</i>	145	45,706	X	X			
Curupaú	<i>Anandenanthera colubrina</i>	48	45,122	X	X			

Source: MAGDR (1998).

^a Includes value-added products; sawn wood, however, accounts for 75 percent of export volume and 60 percent of export value. Total volume of exports is 108,800m³ with a total value of approximately \$76 million.

A Linear Programming Model to Analyze Land Conversion

Linear programming is a general optimization technique that can be used to examine the optimal allocation of scarce resources (Buongiorno and Gilles 1987). The methodology has been used successfully for many years in operations research for both agricultural and forestry production (e.g., Howard 1993, Nicholson et al. 1994, Osho 1995), and in the empirical estimation of deforestation at the household and firm level (Kaimowitz and Angelsen 1998).

The model presented here is a multi year dynamic optimization model that examines a joint cattle and timber production scenario, and evaluates how selected

parameters will affect the rate of land conversion from timber to pasture. The model has a twenty-year time horizon, separated into ten periods of two years each. The objective function maximizes the net present value of terminal year capital assets and biannual disposable income. Capital assets are described by land, both in forest and pasture, and the cattle herd. Disposable income is the cash that the landowner can remove from the system every two years during the 20-year horizon. The mathematical structure of the model is presented below.

Mathematical Structure and Description

$$\begin{aligned}
 & \text{Max } \sum_{s=1}^T (1+r)^{-s} W_t + (1+r)^{-T} V H_T + (1+r)^{-T} V F_T + (1+r)^{-T} V P_T \\
 & \quad \text{s.t.} \\
 & \text{CSH}_t - \text{CSH}_{t-1} - \text{TI}_t - \text{SB4}_t - \text{SH2}_t + \text{NCC}_t + \text{PCB}_t + \text{MC}_t + \text{PT}_t + \text{DI}_t = 0 \\
 & \quad F_t + \sum_{s=1}^t P_t \leq 3,000 \\
 & \quad -\text{DI}_t + W_t \leq 0 \\
 & \quad \text{TI}_t - (\text{NRF})F_t = 0 \\
 & \quad \text{TH} - \frac{1}{\text{SR}} \sum_{s=1}^t P_t \leq 0 \\
 & \quad \text{TH}_t - \text{TC}_t - \text{BL}_t - \text{B2}_t - \text{B4}_t - \text{H2}_t = 0 \\
 & \quad \text{TC}_{t+1} - (1 - \text{CR})\text{TC}_t - \text{BC}_t - \text{HF2K}_t = 0 \\
 & \quad \text{BL}_t - (\beta)\text{TC}_t = 0 \\
 & \quad \text{B2}_t - (\alpha)\text{TC}_t = 0 \\
 & \quad \text{B4}_t - (1 - \text{DL})\text{B2}_{t-1} = 0 \\
 & \quad \text{SB4}_t - \text{B4}_t = 0 \\
 & \quad \text{HF2}_t - (\alpha)\text{TC}_t = 0 \\
 & \quad \text{HF2}_t - \text{SH2}_t - \text{HF2K}_t = 0 \\
 & \quad \text{PT}_t - (\delta) \sum_{s=1}^t P_t = 0 \\
 & \quad -\text{TH}_t + \text{VH}_t \leq 0 \\
 & \quad -\text{F}_t + \text{VF}_t \leq 0 \\
 & \quad -\sum_{s=1}^T P_t + \text{VP}_T \leq 0 \\
 & \quad \text{VH}, \text{VF}, \text{VP}, \text{F}, \text{P}, \text{TI}, \text{TH}, \text{SR}, \text{TC}, \\
 & \quad \text{BL}, \text{B2}, \text{B4}, \text{H2}, \text{HF2K}, \text{PCB}, \text{CSH}, \text{DI}, \text{W} \geq 0
 \end{aligned}$$

where t is the period identifier beginning at 1, T is the last year of the model, r is the discount rate, VH is the terminal value of the cattle herd, VF is the terminal value of the forest land, VP is the terminal value of the pasture, F is the hectares in forest, P is the hectares converted to pasture, TI is the timber income, NRF is the net return per hectare of forest, TH is the total cattle herd, SR is the stocking rate, TC is the total cows, BL is the number of service bulls, $B2$ is the number of young bulls, $B4$ is the number of bulls for sale, $H2$ is the number of heifers, CR is the culling rate for cows (includes death loss), BC is the cows purchased, DL is the death loss per period, $SB4$ is the bulls sold, $SH2$ is the heifers sold, $HF2K$ is the heifers kept for the cow herd, CSH is the cash available in any period, TI is the timber income, NCC is the net cost of land conversion, PCB is the cost of buying cows and bulls, MC is the herd maintenance cost, PT is the pasture tax, DI is the disposable income, W is the disposable income withdrawn per period, α is the calving rate of 60 percent, β is the breeding bull to cow ration, and δ is the pasture tax rate.

For the simulations of regional susceptibility an area of 3,000 hectares is initially allocated to the landowner. In the subsequent analysis of forest management costs and land use taxes the initial land allocations are 1,000 hectares and 5,000 hectares. The land is free, and assumed to be of a single quality class and completely forested. The cost of sustainable forest management—for 1,000 and 5,000 hectares—was estimated by the Bolivian Sustainable Forest Management Project (BOLFORD-USAID) and are presented in Table 2.2. These values were prorated for the area of 3,000 hectares.

Each hectare of land earns biannual revenue under a sustainable forest management program. Stumpage volumes were collected from management plans of

regional concessions, and are subject to a universal 4 percent annual allowable cut. A net return per hectare of forest is calculated by subtracting the management costs from the gross value of the allowable cut. The stumpage price is initially set at \$4.00 per M3. Estimates for stumpage prices throughout Bolivia ranged from \$3.53 to \$5.66 (Soto 1996, Cordova 1997). Thus we also include a sensitivity analysis where a range of stumpage values are used. The ending value for forestland is determined as the net discounted value of perpetual sustainable forest production into infinity, also known as land expectation value.

Table 2.2 Base Levels for Model Variables

Description	value	unit	Description	value	unit
CATTLE			GENERAL		
Purchase price cow	250.00	\$/head	Initial capital	0.00	Dollars
Purchase/sales price bull	280.00	\$/head	Discount rate	5.00	Percent
Sales price heifer	200.00	\$/head	Tax on land clearing	15.00	\$/hectare
Annual maintenance cost	12.60	\$/head	Pasture carrying capacity	1.50	ha/head
Calving rate	60.00	Percent			
Culling rate	10.00	Percent			
Annual herd loss	2.00	Percent			

In order to start a cattle herd, the landowner must first convert the land to pasture. Pasture clearing costs were generated through interviews with land clearing companies and ranchers and range from \$350 to \$605, including a \$15 per hectare clearing tax.

There is no initial capital available. It is assumed, however, that at the time of clearing, the landowner will sell all available commercial timber. A 30 percent tax is levied on the sale of timber from cleared lands. Thus, the net cost of land conversion is the cost of clearing minus the value of the stumpage net of taxes. The final pasture land value reflects returns to investment in clearing.

Finally, with standard extensive management techniques employed throughout all regions, cattle production costs are expected to be uniform. Table 2.2 gives the values for variables used throughout the analysis. Cattle production costs were found in the annual publication of agricultural statistics of the Eastern Agricultural Association (CAO 1997). In addition, most sales occur at a few abattoirs in major metropolitan areas and so prices for beef products are expected to be similar, at \$1.50 per kilo, across regions. The major difference between the regions is transportation, and indeed, the cost of getting cattle to and from the ranches varies tremendously. For example, it costs \$35.18 to transport an animal to market from the Guarayos region, but \$105.16 from the Pando. Transportation costs were estimated in through informal interviews with transportation associations, ranchers, and individual truckers. These transportation costs, in addition to the values for other selected program variables, are shown in Table 2.3, and illustrate all of the important regional differences.

Results

The results presented in this section cover a variety of the land conversion issues in the Bolivian Lowlands. First, regional susceptibility to conversion. Here it is argued

that due to different productive potential, both in cattle and forestry, individual regions will experience different levels of conversion pressure.

Second, the results examine the impact of increasing net returns to forestry on land conversion to pasture (i.e., changes in stumpage volumes and prices). Results for both total land converted after 20 years and the rates of land conversion during the 20 years of the model run are shown. Subsequently, the results of variations in forest management costs and land taxes are presented.

Table 2.3 Regional Variation for Selected Variables

Variables	Unit	Chiquitanía	Guarayos	Pando	Andean Foothills	Paraguá
Total stumpage volume	m ³	40.00	65.00	73.00	75.00	83.00
Annual allowable cut	M ³	1.60	2.60	2.92	3.00	3.32
Stumpage value	\$/m ³	4.00	4.00	4.00	4.00	4.00
Net returns per hectare forestry	\$/ha	1.76	5.76	7.04	7.36	8.64
Value forest land	\$/ha	35.20	115.20	140.80	147.20	172.80
Pasture establishment	\$/ha	350.00	495.00	550.00	555.00	605.00
Net Stumpage revenue	\$/ha	112.00	182.00	204.00	210.00	232.00
Value pasture land	\$/ha	238.00	313.00	345.00	345.00	373.00
Cattle transport costs	\$/hd	39.40	35.18	105.16	55.66	70.68

Regional Productivity and Land Conversion

The site descriptions are of the five regions examined in the analysis are given below, followed by the respective land conversion estimates. The regions stretch across the length of the Bolivian Lowlands and cover most of the area where there is potential for conflict between cattle production and forestry (MDSMA 1995, ITTO 1996). It is important to note that the geographic references for are for the purpose of this study only, and although they bear some resemblance to actual regions, the borders are those shown in Figure 2.1. The regions are described as (1) Chiquitanía, (2) Guarayos, (3) Paraguará, 4) Andean Foothills, and (5) Pando.

Chiquitanía

Situated east of the Beni plains and comprising approximately 7 million hectares, the Chiquitanía site is on the Brazilian Shield and averages 1,000 meters above sea level (m.a.s.l.). It is an undulating terrain with mostly subtropical dry forest that receives annual rainfall from 900-1,200 mm. This region has a seven month dry season allowing harvest operations for six to seven months of the year. The soils have the following characteristics: poor chemical content, well-drained, red clay soils, acidic, high exchangeable aluminum, and low fertility (oxisols, ultisols). There has been a permanent settlement in this area for a long period, primarily by indigenous populations and there is a high level of cattle production activity (Killeen 1991). The forest is comprised mainly of very dense hardwoods with no mahogany.

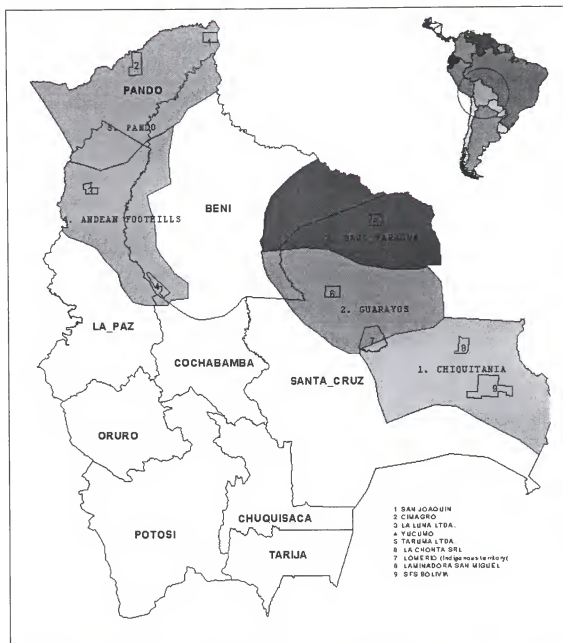


Figure 2.1 Geographical Site Descriptions for Five Regions in the Bolivian Lowlands

Guarayos

The Guarayos region is located immediately northwest of Chiquitania and covers approximately 8.5 million hectares. As part of the Brazilian Shield it shares many characteristics with the Chiquitania. The primary difference is a higher annual precipitation of approximately 1,800 mm. It is classified as a subtropical moist forest. The soils are primarily well-drained, red clay soils, high exchangeable aluminum, and low fertility (oxisols, ultisols). Harvest operations in this area can take place four to five months of the year but are impeded by heavy rains during the wet season. The Guarayos site contains forest with mixed inventories of hardwoods and softwoods. Mahogany occurs in low volumes. There is a strong presence of cattle production in this region.

Paraguá

The Paraguá area represents a region of approximately 5.5 million hectares. It is a subtropical moist forest that receives an annual rainfall of 1,600 mm and is an average of 800 m.a.s.l. For the most part the soils are well-drained, red clay soils, with low fertility (oxisols, ultisols). Located in the far northeast section of the Department of Santa Cruz, and the southeastern section of the Department of the Beni, this remote region has poor infrastructure and very low population pressures. Transportation costs for both agricultural and forestry commodities are very high with log trucks often taking three to four days to reach Santa Cruz—for a distance of between 500 and 800 kilometers. The dry season is prolonged and severe, allowing forest harvest for five-six months, but creating problems for agricultural production. There is currently little cattle production activity in

activity in the area. There are a high percentage of dense hardwoods, and a low-medium frequency of mahogany.

Andean Foothills

The area described here as the Andean Foothills stretches through the Departments of La Paz (central) and the Beni (western); east from the Andean foothills, and west, southwest of the natural grasslands of the Beni. The Andean Foothills region is a subtropical moist forest, covering 5 million hectares, with an average annual rainfall of 2,000-2,800 mm. This area is an ancient alluvial plain with sandy loam soils of variable texture and adequate fertility. Poor drainage and high rainfall combine to create frequent flooding, saturated soils, and very difficult production conditions for six months of the year. The timber harvest season is limited to three months per year, but regardless, has good forestry potential. The forest is comprised mainly of white, softer woods, with Ochoó (*Hura crepitans*) being the dominant species. There are strong colonization pressures in some areas in this site, and a moderate level of cattle production.

Pando

This region lies within the new forestry frontier and consists of the far north of the Department of La Paz and the entire Department of Pando. It has received 19 new concessions, totaling 1.5 million hectares, in the Department of Pando alone, since the passing of the new forest legislation. Precipitation ranges from 1,800-2,000 mm and there are only three dry months. The predominant soils are again oxisols and ultisols. The forests are considered to be more productive than in the Guarayos and Chiquitaniá sites, but higher precipitation constrains the harvesting season duration. Cattle production options are low, however, with considerable market and transportation constraints.

Regional Susceptibility to Land Conversion

The simulation results for the individual regions clearly demonstrate differences in susceptibility to land conversion. Table 2.4 shows the simulation results for land conversion rates for the five regions. The results are for total area converted after 20 years, total percentage conversion, and an annual rate of conversion.

Table 2.4 Regional Comparison of Land Conversion to Pasture (3,000 Hectare Area)

Result	Andean				
	Guarayos	Chiquitanía	Foothills	Paraguá	Pando
Hectares converted (20 yrs)	804	651	0	0	0
Percent conversion (20 yrs)	27 %	22 %	0 %	0 %	0 %
Annual rate ^a	1.3 %	1.1 %	0 %	0 %	0 %

^a. The average annual rate of deforestation for Bolivia is approximately 0.50 % (Pacheco 1998).

The Guarayos and Chiquitanía regions were the two regions most susceptible with 27 and 22 percent conversion, respectively, over the 20-year simulation timetable. This reflects average annual conversion rates of 1.3 percent for Guarayos and 1.1 percent for the Chiquitanía. In the other three regions described by the Andean Foothills, the Pando and Paraguá there appears to be little risk of land conversion with 0 percent converted over the 20-year period.

These results accurately reflect the population distribution of cattle in the Bolivian Lowlands—outside of the Beni plains. The two areas shown to be more susceptible to land conversion both have good access to markets and reasonable forest productivity. This means that cattle transportation is cheap making ranching relatively more profitable, and that forest production can provide the capital needed to begin the land conversion

process. Further examination for variations was conducted on the Guarayos region. In this case the model was run with changes in stumpage volumes and values to capture the effect of increasing returns to forestry on land conversion to pasture.

Stumpage Values and Land Conversion

The forestry component of the model was then varied, using the base data from the Guarayos region, to incorporate a range of stumpage volumes and prices. The combination of stumpage volume and price creates stumpage values. This means that areas can have different stumpage volumes, but depending on the stumpage price, could have the same total stumpage value. The simulation results are shown in Figure 2.2. It can be seen that, to a point, higher stumpage prices, and thus stumpage values, induce greater land conversion after 20 years.

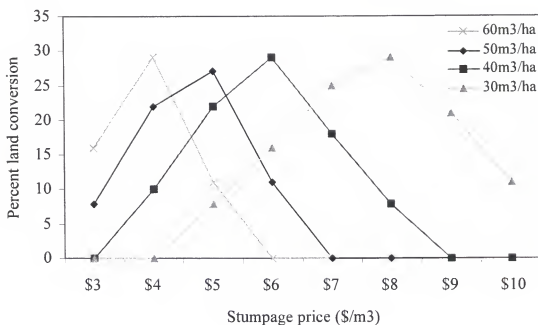


Figure 2.2 Percent Land Conversion by Initial Stumpage Volume and Prices

Each of the four lines in the graph represent individual stumpage volumes. In the simulations, the stumpage price is set and the estimate of total land conversion after 20 years is generated. Thus, each point on the graph represents the total land converted after 20 years under a given stumpage value condition. The stumpage price is then changed to a higher value. For example the stumpage price starts at \$3.00 per M3 for a land area that has a stand density of 40 M3 per hectare (the penultimate line on Figure 2.2)- the next run of the model is then done with a stumpage price of \$3.50 per M3. In this manner we can compare the impact of higher stumpage prices, and thus stumpage value, on land conversion.

The result shows that as eventually a sufficiently high stumpage value will ensure that no land is converted to pasture but, prior reaching that level, a higher stumpage value can allow more land to be converted because forestry is generating the capital necessary to convert to pasture. Each starting stumpage volume scenario has a similar pattern but an individual timetable. For example in stands with stumpage volumes of 60M3 per hectare, the pattern will occur at lower stumpage prices than in a stand with only 30M3 per hectare. This is because the pattern is based on stumpage value (volume times price). It should be noted that a stand of 30M3 with a stumpage price of \$6.00/M3 will have the same stumpage value as a stand of 60M3 with a price of \$3.00/M3.

This result illustrates a problem with the current paradigm that higher stumpage values will lead to less land conversion. While that paradigm remains correct at a certain high stumpage values, at lower stumpage values, the capital generated by forestry is used only as a source of funds to convert land to the more profitable alternative - pasture. Therefore policies that raise stumpage values- these could be as varied as improved

infrastructure or export taxes—may have the unwanted effect of inducing land conversion. Stumpage values must reach a sufficiently high level for forestry to be marginally more profitable than other land uses and not be only a source of additional capital for land clearing.

Forest Management Costs and Land Conversion

The current law also requires preparation of land use plans for privately-owned forest properties. Individual land use plans are similar to the requirements faced by the forest concessionaires. Individual land use plans require the classification of areas for intensive annual cropping, perennial crops, pastures, open grazing, and forestry. The plans also prescribe minimum conservation practices. Individual property land use plans are to be registered with land titles and become legal zoning restrictions or easements applying to current and future owners. Just as with forest management plans for concessionaires, individual property land use plans are prepared by professionals who must be hired by the landowners. These land use plans are expensive and have a definite scale bias against the smaller land holders. Table 2.5 shows the per hectare costs of preparing a forest inventory and management plan where the smallest holding of 500 hectares pays a startling \$30.93 per hectare and the largest example of 200,000 hectares pays only \$0.11 per hectare.

The costs associated with sustainable forest management, which include a forest inventory and management plan were further detailed by the Bolivia Sustainable Forestry Project (BOLFOR), and are estimated at \$6.50 per hectare for 1,000 hectares and \$2.68 per hectare for 5,000 hectares (Table 2.6). The planning and management process incurs both

Table 2.5 Economies of Scale in Forest Inventory Preparation (\$US, 1995)

Area (has)	Photo & map	Planning	Fieldwork	Supervision & transport	Data processing	Document prep.	Total cost	Cost per hectare
100	100	120	325	1,000	48	1,500	3,093	30.93
500	100	120	650	1,000	60	1,500	3,430	6.86
1,000	100	120	975	1,000	95	1,500	3,790	3.79
2,000	100	120	1,300	1,000	144	1,500	4,164	2.08
5,000	100	180	2,080	1,600	220	1,500	5,680	1.14
10,000	250	240	2,925	2,000	250	1,500	7,165	0.72
15,000	330	270	3,575	2,200	257	1,500	8,132	0.54
20,000	400	300	4,095	2,400	266	1,500	8,961	0.49
25,000	480	330	4,615	2,600	280	1,500	9,805	0.39
30,000	550	360	5,005	2,800	296	1,500	10,511	0.35
50,000	850	420	6,500	3,000	370	1,500	12,640	0.25
100,000	1,600	480	9,165	3,400	450	1,500	16,595	0.17
200,000	3,100	600	12,935	4,000	550	1,500	22,685	0.11

Source: Bolivian Sustainable Forest Management Project (BOLFOR) – published as “Normas técnicas para la elaboración de instrumentos de manejo forestal.” Resolución Ministerial No. 62/97, La Paz, Bolivia (1997:V-46).

Table 2.6 Costs of Sustainable Management on Private Forests of 1,000 and 5,000 Hectares

Activity	1,000 hectares		5,000 hectares	
	Initial (\$US)	Yearly (\$US)	Initial (\$US)	Yearly (\$US)
Planning				
Preparation of management plan and inventory	2,510		3,963	
Preparation of annual operating plan and census		2,250		4,450
Production				
Road Building	1,800		3,600	
Supervision		2,691		5,336
Marketing		700		2,100
Total Costs	4,310	5,641	7,563	11,886
Depreciation of Initial Costs		862		1,513
Average Annual Cost Per Hectare		6.50 ^b		2.68 ^b

Source: Bolivian Sustainable Forest Management Project (BOLFOR 1996).

^b Forest land use taxes not included

initial and annual costs. Since these plans are only good for five years, after which time they must be renewed, initial costs are depreciated over this period. In this estimate, the two of the major costs are the preparation of the management plan and inventory and the preparation of the annual operating plan and census. These costs show marked differences in the per hectare costs between 1,000 and 5,000 hectares. Management plans and inventory are estimated to cost \$2.51 per hectare for an area of 1,000 hectares and \$0.79 per hectare for an area of 5,000 hectares.⁴ Similarly, the cost of preparing annual operating plans and the harvest area census are estimated at \$2.25 per hectare for 1,000 hectares and \$0.89 for 5,000 hectares.

⁴ These estimates are slightly lower than the estimates in Table 2-6 but show similar economies of scale.

Impact of Forest Management Costs on Land Conversion

Table 2.6 gave the forest management costs for an area of 1,000 acres as \$6.50 per hectare (hereafter referred to as high management costs) and \$2.68 per hectare for an area of 5,000 hectares (low management costs). The model was run, with average cattle production inputs, to compare these two forest management cost scenarios on both land areas.

The results show that we can expect 5 percent of the total land area to be converted to pasture after 20 years on a 1,000 hectare area with high management costs. On a 5,000 hectare block, with low management costs, one can expect 11 percent of the land area to be converted to pasture after 20 years.

In effect, low management costs allowed a greater net return to forestry as detailed above and thus encouraged land conversion—the opposite of what one might expect. The combination of larger income from forestry (an extra 4,000 hectares per year) and lower management costs created the capital that is needed to overcome the costs of land conversion and allow investment in cattle production.

Land Use Taxes and Land Conversion

Under the new agricultural and forestry laws new regimes have been established for taxes and land use planning in forestry; land conversion from forest to other land uses; and land use taxes in pasture land. For forested lands the new Forest Law assesses a per hectare uniform area-based forest land use tax. This tax is currently set at \$1.00 and can be adjusted upward, but can never fall below the \$1.00 value. From the description, the tax is uniform across all ranges of productivity and profitability of forest lands; no compensation is made, for example, for forests with low stand densities, a preponderance of lesser valued species, or for forests in regions with high transportation costs. On

private lands, this tax is assessed annually on the area of harvest. On concessions, however, it is assessed on annually for every hectare regardless of harvest volume or area. The practical side of supervising the forest sector makes ostensibly simple taxation methods, such as uniform area or value taxes, more appealing (Hyde and Sedjo 1992). The uniform taxes appear to require less information on the nature and productivity of the forest, but it is this very information that allows other, more complex, forms to accurately assess the tax, and in the absence of which, the uniform taxes can be inaccurate (Vincent 1990).

For land conversion from forest to any other use, the presentation and approval of an individual property land use plan and land clearing plan is required. Any timber sold as a result of land clearing requires a "certificate of forest origin" and payment of an area and a volume-based tax. The area tax for clearing land is currently set at 15 times the per hectare tax paid by forest concessions, or \$15/hectare. The volume tax is computed at 30 percent of the value of timber at the land clearing site, according to a price list established by the Superintendencia Forestal. The landowner pays 15 percent of the value and the buyer pays the other 15 percent. From a practical standpoint, if the landowner finds the value taxes overly burdensome the timber will be burnt off, which is, indeed, common practice.

Land converted to pasture incurs a progressive tax based on the total land value declared by the owner; the scale begins at 0.35% and increases to 1.50% of the value without improvements (Table 2.7). Actual land prices for cleared pasture land may be as high as \$500 per hectare in accessible areas along major roads in regions such as the Chiquitanía of Santa Cruz. Outside these zones, however, prices decrease dramatically to \$20 or lower. Generally, pasture lands with limited access may be valued between \$100

and \$250 per hectare. Depending on the size of ranches and the total value, taxes on land cleared and planted to pasture are typically between \$0.20 and \$0.50 per hectare.

Table 2.7 Land Tax Schedule for Livestock Ranches, 1996

Declared total value (\$US)	Fixed tax (\$US)	Plus variable rate (%)	On amount over (\$US)
0 to 40,800	0	0.35	0
40,800 to 82,000	143	0.50	40,800
82,000 to 122,500	347	1.00	82,000
> 122,500	756	1.50	122,500

Source: Ley INRA (1997)

Impact of Changes in Land Taxes on Land Conversion

Using the two production scenarios from the analysis of the forest management costs, the model was rerun to examine the impact of changing land taxes on land conversion to pasture. In this case, four scenarios were examined and results are presented below in Table 2.8.

Table 2.8 General Land Conversion Impacts with Changes in the Land Use Taxes

Area (ha)	Tax change	Impact on conversion	Comment
1,000	Forest tax increase	No change	Forest tax low therefore little impact when increased.
5,000	Forest tax increase	No change	Forest tax low therefore little impact when increased.
1,000	Pasture tax increase	No change	No capital available for land conversion therefore taxes are irrelevant.
5,000	Pasture tax increase	Decrease in total land conversion.	Effective measure of land conversion control.

To further illustrate the results, Figure 2.3 shows the results when the model was run with the forest tax held constant at its current rate of \$1.00 per hectare, and the pasture tax varied increased from its estimated rate of \$0.50 to a rate of \$2.00 per hectare for both small and larger areas (1,000 and 5,000 has), with their respective forest management costs. On the larger area, the results showed a steady decline in land conversion to as the tax on pasture land increases, until there is no conversion at \$2.00. On the 1,000 hectares, however, increasing the pasture tax had little effect on the overall rate of land conversion. Results in Table 2.9 further develop this idea for the area of 5,000 hectare; in this case, the pasture tax is held constant (at \$0.50 per hectare) and the forest land tax is varied from \$0.00 to \$2.00 per hectare. This results shows the land conversion rate unchanged. These results suggest two points (1) that under conditions of high forest management costs, relative land taxes are not a determinant of land conversion; and (2) under conditions of low forest management costs, changes in pasture taxes are more effective determinants of land conversion than forest taxes.

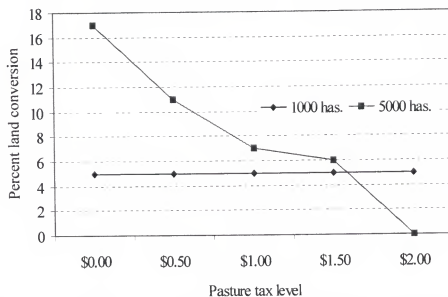


Figure 2.3 The Effect of Pasture Taxes on Land Conversion under Conditions of High and Low Management Costs

Table 2.9 Variations in Forest and Pasture Land Taxes: Their Effect on Land Conversion (5,000 hectares)

Forest Land Tax (\$/ha/yr)	Pasture Land Tax (\$/ha/yr)	Land Conversion (%)
variation in forestry tax		
\$0.00	\$0.50	11 %
\$0.50	\$0.50	11 %
\$1.00	\$0.50	11 %
\$1.50	\$0.50	11 %
\$2.00	\$0.50	11 %
variation in pasture tax		
\$1.00	\$0.00	17 %
\$1.00	\$0.50	11 %
\$1.00	\$1.00	7 %
\$1.00	\$1.50	6 %
\$1.00	\$2.00	0 %

Conclusion

The recent release of land from forest concession to private ownership stands to increase the availability, and incentive, of land to be converted from forestry to alternative land uses in the Lowlands of Bolivia. The monitoring and control of forest production on both private and public land is in the hands of the Superintendencia Forestal, and it is important that this agency be able to efficiently allocate its limited resource to best support sustainable forest production throughout the Lowlands. In public forest lands-concessions-the task is relatively simple; ensure the compliance with prescribed best forest management practices. On private lands, however, sustainable forest management is complicated by the option to convert to other, more profitable, land uses. The SF must

then manage these lands with the heightened concern over the potential for land conversion.

This paper inquires into the potential interaction of two important land use options in the Lowlands—sustainable forestry and cattle production—under the new economic parameters of the land use legislation adopted by Bolivia in 1996/97. We show that regional variation in productivity, forest management costs, and land use taxes all affect the likelihood of land conversion. The results show that land taxes and land use planning requirements which increase marginal costs of forestry need careful consideration before broad application.

The simulation results clearly indicate that the two regions of the Brazilian shield, Chiquitania and Guarayos are higher risk areas, and will likely suffer the most conversion from forest to pasture. All of the other regions—the Andean Foothills, Paraguá, and Pando—appear, under current conditions, to be in little risk of major land conversion within the next 20 years; due both to high forest productivity as well as poor cattle production conditions.

Then land conversion will vary when subject to changes in net returns to sustainable forestry were examined. The results show that when the annual returns from sustainable forestry production release an initial capital constraint, and are used to compensate for the costs of land conversion, more land is converted to pasture. Eventually the marginal benefit of forestry becomes sufficiently high to negate any conversion to pasture but, there are circumstances, that policy makers and land use planners must address, when increasing marginal returns to forestry can, indeed, exacerbate land conversion to pasture.

The results also imply that forest management costs which include land use planning requirements can drastically affect the level of land conversion - with higher forest management costs increasing land conversion to pasture. All else equal. Finally, these results suggest two points (1) that under conditions of high forest management costs, relative land taxes are not an important determinant of land conversion; and (2) under conditions of low forest management costs, changes in pasture taxes are more effective determinants of land conversion rates than forest taxes.

The policy implications of this work lie in the freedom to vary land taxes and land use requirements to minimize land conversion. At present forest land taxes in Bolivia are set at a national level. This work shows that increased flexibility would encourage sustainable forest production in marginal regions and thus reduce the risk of land conversion to other uses.

CHAPTER 3

FACTORS AFFECTING BOLIVIAN MAHOGANY EXPORTS WITH POLICY IMPLICATIONS FOR THE FOREST SECTOR

Introduction

The worlds' tropical forests are an enigmatic and fragile resource and, although the focus of two decades of international debate, continue to suffer from mismanagement and deforestation. Of the familiar culprits associated with deforestation—slash and burn agriculture, cattle production, industrial agriculture, and timber harvest—it is accepted that timber harvest is the least environmentally damaging (Burgess 1993). However, it remains true that the selective harvest of high-grade species, a common practice in tropical forestry, leads to lower timber value in the forest, and thus can become the first step toward land conversion. A poignant example of which can be found in the eastern lowlands of Bolivia where, for the past 20 years, unregulated extraction of mahogany (*Sweitenia macrophylla*) has been the norm in the forestry sector, while the area under agricultural production has increased dramatically. To buffer the expanding agricultural margins and at the same time provide economic benefits, a stable timber industry with long-term management plans is perceived as a desirable social goal.

Unfortunately, the transience of the timber industry throughout the tropics is notorious and exemplified by the “boom and bust” cycle of timber exports; a cycle described by high initial earnings from the export of old growth timber, depletion of the

resource, and eventual failure of the processing industries (Vincent 1992). The two common factors underlying this cycle are low or inadequately rising timber prices and inefficient government policies in both the forest and non forest sector. The former fails to reflect local scarcity and tropical timber production costs, and the latter provides perverse incentives for land use that neglect public goods arising from continual, sustainable tropical forest production (Repetto 1987; Repetto and Gillis 1988; Vincent 1990; Barbier 1991; Binswanger 1991; Deacon 1995).

As a first step toward understanding these markets and improving policy decisions, a simple, empirical model is developed to quantify the factors that affect mahogany export supply and demand, and, to our knowledge, is the first econometric study that attempts to quantify factors specifically affecting mahogany exports from Bolivia. The only other formal model of timber trade in Bolivia is a World Bank study (Anderson et al. 1995) that examines the impacts of the 1985/86 structural adjustment program on the total sawn wood trade.

Three main conclusions arise from our model results that have potentially significant policy implications for the forest sector. First, the results lend some support to largely undocumented observations that commercial mahogany stocks are on the decline. Second, policies that, either directly or indirectly, focus on controlling the total area under production (concession area) are likely to be ineffectual in reducing mahogany extraction and export. Third, mahogany export supply is price elastic, suggesting that pricing policies may be effective in controlling mahogany exports.

The remainder of the introduction gives a brief overview of mahogany export trends and a review of Bolivian forest policy. Subsequent sections describe the model, the data, and the model results. The concluding section discusses policy implications.

Bolivian Mahogany Exports

Approximately 51 percent of Bolivia's 1,100,000 Km² is covered in forest (Lopez 1993). All of the tropical forest is located in the lowlands of eastern Bolivia, which incorporates the Departments of Santa Cruz, Beni, Pando, and northern La Paz. Of these departments, Santa Cruz has been the most important, recording an average of 60 percent of official total log production and 80 percent of mahogany exports during the period 1980-1993; accounting for a total export value of \$US 44.5 million in 1994 (CNF 1995). Although diversifying, the forest sector still depends heavily on a few products, notably the export of mahogany sawn wood. Total mahogany exports from Bolivia (Figure 3.1) reveal a peak of 31.5 million board feet¹ (MMBF) exported in 1979. During a period of economic instability between 1982 and 1986, the average export volume decreased to about 9 MMBF per year. After 1986 export volumes increased until 1989 when 20 MMBF were exported but have subsequently declined to 13 MMBF in 1994. The best Bolivian mahogany has historically been destined to the U. S., while lower grades have gone to Argentina. For example, in 1995, 39 percent of total volume but 44 percent of total value went to the U. S. Together these two destinations consume, on average, 90 percent of total Bolivian mahogany exports. It is now commonly presumed, but largely

¹ At 424 BF/M³ this would lead to cubic meter values of 74,292 M³ in 1979, 21,226 M³ during 1982-1986, 47,170 M³ for the year 1989, and 30,660 M³ in 1994.

undocumented, that mahogany stocks are in serious decline and, with continued extraction, may become commercially extinct (Stolz and Quevedo 1993). This has led to a serious reconsideration of forest policy in Bolivia.

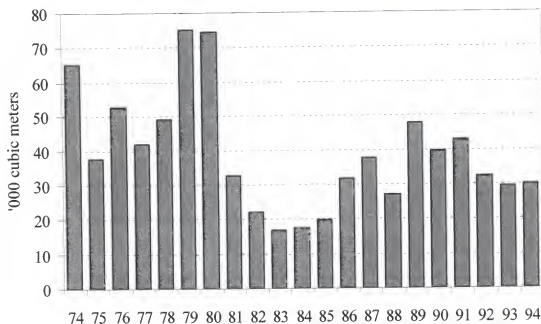


Figure 3.1 Mahogany exports from Bolivia, 1974-1993

Bolivian Forest Policy

Since the passage of forest legislation in 1974, use of the Bolivian forest resource has been in the form of cutting contracts similar to forest concessions. To be granted a concession permit under that law, applicants had to delineate an area not previously demarcated, show sufficient funding for investment in processing facilities, generate a management plan, register with the forest ministry, and begin harvest. Concessionaires were granted cutting contracts to harvest the timber as described within their management plan. They did not, however, own the land nor have rights to use it in any alternative

production. In the past, concessions were short-, medium-, or long-term, with long-term only 20 years. It has been suggested that this policy format, where there is short duration of harvest rights and a lack of land ownership, discourages long term forest management (Vincent 1990; Richardson 1992; Zhang and Pearse 1996).

In response, the government of Bolivia recently passed a new forest law that has drastically altered the dynamics of the forest sector (Nueva Ley Forestal, Ley Numero 1700, del 12 de Julio de 1996). At this time, forest taxes were changed from an ad-valorem tax based on extracted timber value to an annual, area-based tax on hectares under concession. The area-based tax is expected to increase economic efficiency because it has less impact on marginal production conditions than would an ad-valorem tax and is easier to enforce (Just et al. 1982; Hyde and Sedjo 1992; von Amsberg 1994). Further changes in the new law include lengthening concessions terms to 40 years and allowing concessions to be traded. So far, the effect of this law has been an immediate reduction of approximately 70 percent in the area under concession in the Department of Santa Cruz, from 14.7 million to 4.3 million hectares.

Model

To examine the supply and demand relationships in the export market of Bolivian mahogany, a system of simultaneous equations using quarterly data over the period 1977-1993 is developed. Two equations model the supply and demand for exports. A third equation is used to endogenize domestic price in the form of a reduced form price equation.

Mahogany export supply (ES) is modeled as a function of the variables listed in equation 1 and Table 3.1. They include the export price for mahogany (EP, +) and the domestic price (DP, -), which addresses the option of the producer to sell in the domestic market. In timber market models, standing stock or inventory is commonly used as a supply shifter (e.g., Adams and Haynes 1980). Unfortunately, time series data on mahogany inventory in Santa Cruz is unavailable; therefore, a time trend variable (TM, -) is used as a proxy for assessing the status of available commercial inventory. The time trend does not model mahogany stocks but rather their flow. We assume that, all else being equal, a decreasing flow trend implies a related decline in the available inventory. The area under concession variable (CH, +) is used to assess the impact of the area under concession on the supply of mahogany; one might expect that the larger the area under concession, the greater the quantity of mahogany supplied. Although most of the export trade in forest products in Bolivia are conducted in U. S. dollars (\$US), the exchange rate (ER, +) is included to account for the fact that many other inputs, such as labor and energy, are priced in Bolivianos. In this manner, the exchange rate could still have an impact on supply decisions. A dummy variable (EI, -) tests whether exports of mahogany were significantly different during the period of severe economic instability in the early 1980's. Anderson et al. (1995) focuses on the supply variation during and immediately after the period of economic crisis in the early 1980s. Their results suggest that much of the apparent increase in timber exports during the period 1984-1991 was due to improved reporting after the economic crisis. This raises questions about the quality of the official data during the period of economic crisis. We agree that there is cause for concern and attempt to pick up the variation with the use of a dummy variable for that period. Lagged

exports (LE, +) account for inertia in supply, which is expected to be present in quarterly data. This partial adjustment process allows us to calculate both short- and long-run supply elasticities. Finally, precipitation (PP, -) is important in determining seasonality of timber supply in Santa Cruz due to the poor road conditions during the rainy season.

Mahogany export demand (ED) is modeled as a function of the variables listed in equation 2 and Table 3.1. Demand is also a function of export price (EP, -). All else being equal, it is expected that increases in Gross Domestic Product (GDP) and population will shift the demand for exports. Therefore, GDP and population figures are included for both the U. S. (UG, +) (UP, +) and Argentina (AG, +) (AP, +). To account for substitution effects, cherry prices were chosen as the substitute for the U. S. (USB, +). In Argentina, data limitations required that an average price of hardwood imports (ASB, +) be used. In discussion with exporters and importers of mahogany from Bolivia to the U. S., the importance of Brazilian mahogany production as a competitive product was constantly mentioned. However, data for Brazilian mahogany production is not available to the authors at this time, so total sawn wood production (B.P., -) is used as a proxy. Finally lagged exports (LE, +) are used to account for short run capacity constraints, once again allowing for the calculation of both short- and long-run demand elasticities.

The third equation in the system introduces an instrumental variable for domestic price. Initially, it was hoped that we could model the domestic supply and demand for mahogany separately from exports, but due to data constraints this was not possible. Therefore, an instrumental variable for domestic price (DP) was developed using the following variables: Bolivian GDP and population (BG & BP), a dummy variable for

Table 3.1. Data description and sources

Variable	Description	Source
Equation 1		
Dependent		
ES	Export supply of mahogany	CNF Annual reports
Independent		
EP	Mahogany export price	La Chonta Sawmill
CH	Cumulative area under concession	CDF
PP	Precipitation	CORDECRUZ
ER	Official exchange rate	Banco Central de Bolivia
EI	Dummy variable for economic instability	
LE	Lagged exports	
TM	Time trend variable	
DP	Domestic price for mahogany	La Chonta Sawmill
Equation 2		
Dependent		
ED	Export demand for mahogany	CNF Annual reports
Independent		
EP	Mahogany export price	La Chonta Sawmill
UG	Gross Domestic Product USA	U. S. Business Statistics
UP	Population USA	U. S. Business Statistics
AG	Gross Domestic Product Argentina	ECLAC Stats. Yearbook
AP	Population Argentina	
USB	Price of U. S. substitute hardwood	ECLAC Stats. Yearbook
ASB	Avg. price hardwood imports Argentina	\$USA Forest Service
BRP	Brazilian sawn wood production	FAO Yearbook
LE	Lagged exports	FAO Yearbook
Equation 3		
Dependent		
DP	Domestic price for mahogany	La Chonta Sawmill

Table 3.1—continued.

Variable	Description	Source
Independent		
BP	Population Bolivia	ECLAC Stats. Yearbook
BG	Gross domestic product Bolivia	
EI	Dummy variable for economic instability	ECLAC Stats Yearbook
ED	Export demand for mahogany	CNF annual reports
IC	Internal consumption of mahogany	CNF annual reports
LP	Lagged production	

economic instability (EI) as used in the export supply equation, total export demand (ED); internal consumption of mahogany (IC), and a lagged total production (LP) of mahogany (exports plus domestic consumption). The signs under each independent variable in equations 1 and 2 indicate the expected impact on the dependent variable. The system of equations is as follows:

$$ES = a_0 + a_1EP + a_2CH + a_3PP + a_4ER + a_5EI + a_6TM + a_7DP + a_8LE \quad (1)$$

$$(+) \quad (+) \quad (-) \quad (+) \quad (-) \quad (-) \quad (-) \quad (+)$$

$$ED = b_0 + b_1EP + b_2UG + b_3UP + b_4AG + b_5AP + b_6USB + b_7ASB + b_8BRP + b_9LE \quad (2)$$

$$(-) \quad (+) \quad (+) \quad (+) \quad (+) \quad (+) \quad (+) \quad (-) \quad (+)$$

$$DP = c_0 + c_1BP + c_2BG + c_3EI + c_4ED + c_5IC + c_6LP \quad (3)$$

In equilibrium, $ES=ED$. Endogenous variables include $ES(=ED)$, EP , and DP .

The system of equations was estimated jointly using Generalized Methods of Moments (GMM), a generalization of 3SLS, whereby the system covariance matrix is allowed to exhibit heteroskedasticity and autocorrelation. GMM minimizes the correlation between

the error terms and the vector of instrumental variables. Details on GMM estimation can be found in Hansen (1982), Newey and West (1987), and Gallant (1987).

Data

Data sources and description are listed in Table 3.1, while Table 3.2 gives summary statistics for selected variables. All data is expressed quarterly. This is the first quantitative examination of this issue, and, although the required data are difficult to collect, we use the best available. Export supply and internal consumption of mahogany were collected from the Camara Nacional Forestal (CNF) annual reports. The export and domestic price data were supplied by the sawmill "La Chonta," a large concessionaire and sawmill company in Santa Cruz. The export price is, on average, almost seven times that of the domestic price. This difference can be explained by two points. First, there is a quality differential between wood sold in the export and the domestic markets. The domestic market generally receives lower quality wood. We are unable to control for quality differentials, however, in our model. Second, domestic prices are for the Santa Cruz market, and the export prices are listed F.O.B. Arica, Chile, so the export prices include a larger transportation cost. Due to the unavailability of time series transportation cost data, it is assumed that transportation represents a constant proportion of total export costs. Both price series were adjusted to 1990 dollars using the U. S. consumer price index. The use of the U. S. price index was necessary because of large distortions in the Bolivian indices and the fact that mahogany is bought and sold using \$US as currency. Data on area under concession were collected from the Centro Desarrollo Forestal (CDF), the government body in charge of the forest sector at the time. Precipitation data were provided by the Santa Cruz land planning agency CORDECRUZ. Exchange rate data are listed in the Banco Central de Bolivia annual reports.

provided by the Santa Cruz land planning agency CORDECRUZ. Exchange rate data are listed in the Banco Central de Bolivia annual reports.

Table 3.2. Summary statistics for selected variables

Variable	Units	Minimum	Mean	Maximum
BP	Million	5,285	6,454	7,705
BG	Million \$US	3,855	4,277	4,918
ED/ES	Thousand BF/quarter (M ³ /quarter)	680 (1,604)	3,989 (9,408)	12,494 (29,467)
IC	Thousand BF/quarter (M ³ /quarter)	406 (957)	1,914 (4,514)	5,594 (13,193)
EP	\$US/ M ³	165	298	475
UG	Million \$US	4,341	5,392	6,469
UP	Million	161	179	196
AG	Million \$US	102	112	133
AP	Million	27	30	33
USB	\$US/M3	571	698	994
ASB	\$US/M3	172	265	390
BRP	Thousand M3	1,596	2,252	2,509
CH	Thousand hectares	259	9,398	16,855
PP	Millimeters	21	127	316
ER	Bolivianos/\$US	1.95	147,894	1,929,201
DP	\$US/Thousand BF	60	105	170

Quarterly data for U. S. Gross Domestic Product and population were found in U. S. Business Statistics 1996, with GDP adjusted to 1992 dollars. Similarly, Argentinean GDP and population are reported in the Statistical Yearbook for Latin America and the Caribbean published by the Economic Commission for Latin America and the Caribbean (ECLAC). Argentinean GDP is given in millions of 1980 U. S. dollars. The prices for cherry were provided by the U. S. Forest Service Southeastern Research Center and are an adjusted average of prices for first and seconds and number one common grades. Data on the average price of Argentinean hardwood imports and Brazilian sawn wood production are reported in the FAO statistical yearbook for forest products. In the domestic price equation Bolivian population and Bolivian GDP data, adjusted to 1980, were reported in the ECLAC statistical yearbook.

Results

Model results are given in Tables 3.3 and 3.4. Most of the estimated model coefficients in both supply and demand equations are highly significant (Table 3.3). In the export supply (ES) equation all variables were significant, and in the export demand (ED) equation, only U. S. and Argentinean substitutes (USB, ASB) were insignificant. Argentinean population (AP) was the only significant variable with an unexpected sign. Individual export supply and demand equations, however, had less than exemplary overall explanatory power, as shown by 0.37 and 0.54 adjusted R^2 values, respectively. A possible culprit for the low R^2 is the poor quality of the available data. With most model coefficients highly significant, however, the results appear sound and the model specification correct. Short- and long-run partial equilibrium elasticities are calculated at the data means (Table 3.4).

The time trend variable (TM) suggests that, all else being equal, there has been a decline in mahogany exports by 64 percent over the study period, or an average of four percent per year. This leads us to assume that there has been a corresponding decline in the overall mahogany stock.

Table 3.3. GMM Estimates of Mahogany Supply and Demand in Bolivia, 1977-1993

Independent Variables	Dependent Vars. Domestic price (DP)		Export Demand (ED)		Export Supply (ES)	
Intercept	97.97	<i>1.97</i>	19,653.1	<i>3.51</i>	11,259	<i>11.84</i>
Bolivian Population (BP)	0.010	<i>1.00</i>				
Bolivian GDP (BG)	-0.012	<i>-2.35*</i>				
Economic Instability (EI)	-16.509	<i>-4.42*</i>			-1,977	<i>-4.91*</i>
Export Demand (ED)	-0.0080	<i>-29.98*</i>				
Internal Consumption (IC)	0.0033	<i>1.84*</i>				
Lagged Production (LP)	0.0035	<i>3.47*</i>				
Export Price (EP)			-5.26	<i>-4.91*</i>	8.16	<i>3.15*</i>
U. S. GDP (UG)			4.13	<i>10.04*</i>		
U. S. Population (UP)			450.37	<i>4.67*</i>		
Argentina GDP (AG)			49.97	<i>4.35*</i>		
Argentina Population (AP)			-3,756.9	<i>-5.30*</i>		
U. S. Substitute (USB)			-2.386	<i>-1.02</i>		
Argentina Substitute (ASB)			0.651	<i>0.15</i>		
Brazilian Production (BRP)			-2.76	<i>-1.80 **</i>		
Lagged Exports (LE)			0.413	<i>2.00*</i>	0.535	<i>3.27*</i>
Concession Hectares (CH)					0.086	<i>3.41*</i>
Precipitation (PP)					-1.13	<i>-3.44*</i>
Exchange Rate (ER)					0.00072	<i>17.99*</i>
Time (TM)					-37.21	<i>-2.18*</i>
Domestic Price (DP)					-132.94	<i>-7.29*</i>
Equation R ² :	0.13		0.54		0.37	
Test of overidentifying restrictions: $5.69 < H^2_{28,0.01}$						

t statistics in italics.

* p <= 0.01 ** p <= 0.05

Table 3.4 Partial Equilibrium Effects in Mahogany Supply and Demand

Mahogany Supply (ES)			Mahogany Demand (ED)		
Variable	Short Run Elasticity	Long Run Elasticity	Variable	Short Run Elasticity	Long Run Elasticity
EP	1.43	3.08	EP	-0.93	-1.58
CH	0.20	0.43	UG	5.58	9.51
PP	-0.04	-0.09	UP	20.25	34.50
ER	0.027	0.06	AG	1.40	2.39
DP	-3.50	-7.53	AP	-28.25	-48.13
			USB	-0.42*	-0.72*
			ASB	0.04*	0.07
			BRP	-1.56	-2.66

* underlying coefficient not significant

The area under concession variable (CH) is inelastic with a short-run partial elasticity of .20, and a long-run partial elasticity estimate of only 0.43. This would imply that a change in the area under concession would have a less than proportionate change on mahogany export supply. And therefore policies that affect the area under concession will have limited impact on the quantity of mahogany supplied.

Results also indicate an almost unitary demand price (EP) elasticity, and a short-run export supply price elasticity of 1.43. Mahogany consumers thus appear less responsive to price changes than suppliers. This implies that export taxes levied by the producing nations may be a more effective policy instrument. In addition, the domestic short-run cross-price supply elasticity of -3.5 indicates a strong substitution effect in the

domestic market. With many cheap hardwood alternatives, however, it is unlikely that domestic prices will rise to the point where exports are largely diverted to the domestic market.

As expected, mahogany export supply response to changes in exchange rates (ER) is shown to be negligible. This result runs contrary to studies that suggest exchange rates significantly affect forest product exports (e.g., Kaiser 1984; McCarl and Haynes 1985; Anderson et al. 1995) and others who tender that exchange rates can have a significant impact on deforestation rates and forest degradation (e.g., Kaimowitz et al. 1997). It is, however, consistent with the idea that most of the transactions in forest product export trade in Bolivia are conducted in \$US, therefore the exchange rate would have minimal impact.

The dummy variable representing the period of economic instability (EI) indicates that during that period (1982-1985) there was a 50 percent drop in mahogany exports. This result agrees with the World Bank study (Anderson et al. 1995) that suggests a statistically significant change in exports during the period of economic instability. However, our result does not attest to the cause of this decline. The lagged export variable (LE) reported reasonable inertia conditions in both the supply and demand equations. In partial adjustment models using quarterly data such as this one, this result is to be expected. Interestingly, Bolivian mahogany exports exhibit an elastic response of 1.56 to Brazilian sawn wood production (BRP), which implies that Brazilian production can have affect Bolivian mahogany exports. Finally, the demand shifters GDP (UG, AG) and population (UP, AP) appear to have significant impact on mahogany exports. We

are, however, unable to explain the unexpected sign on the Argentinean population variable (AP).

Conclusions and Policy Implications

For the past 20 years, the Bolivian forestry sector has been dominated by the selective harvest and subsequent export of mahogany; and although it is often presumed that mahogany stocks are in decline, there is precious little inventory data to back up such claims. In addition, the new forest legislation in Bolivia, enacted in 1996, has been touted as the best means by which to control the forestry sector and its principal resources. This paper presents a market model that lends some support to the claim that mahogany stocks are declining but also brings into doubt the potential of the new legislation to control the harvest and export of an individual species such as mahogany.

The model suggests that there has been a decline in mahogany exports of four percent per year over the study period. And, because mahogany, where available, is usually the first species extracted from the forest, it can be assumed that this decline in exports relates directly to a decline in mahogany inventory. Mahogany has been the primary export species and is potentially an important generator of foreign currency for the Bolivian government, and it is hoped that documentation of this decline in supply will provide impetus for policies that sustain remaining inventory.

What policies are likely to be useful? The results indicate that controlling the total number of hectares under concession has a less than proportional impact on exports supplies. It would appear that the area-based tax mechanism may affect the sector as a whole but is not as effective in controlling the supply of an individual species that is

harvested at the frontier. And, unfortunately for the commercial stock of mahogany, this is the current mechanism through which the Bolivian government is managing its forest resource.

The more viable option for controlling mahogany extraction is pricing policy. Indeed, the results show that export supply is sensitive to both export and domestic prices. Without explicit analysis of the domestic market, however, accurate estimates of the degree that total harvest (export supply and internal consumption) is sensitive to variation in export price is not possible. However, because the domestic market is limited it is likely that the total mahogany harvest is very sensitive to export prices.

Therefore, policies that reduce stumpage values, such as ad valorem or export taxes, may be the best option to sustain the remaining mahogany stocks for the near future until more sustainable forest management practices are adopted.

CHAPTER 4

THE LAW OF ONE PRICE AND U. S. MAHOGANY IMPORTS FROM BOLIVIA AND BRAZIL

Introduction

For countries in Latin America and Africa, mahogany has long been an important element of their forestry sector. This is particularly true for Central America, where mahogany has been exported since the 16th century, and heavily since the 18th. In South America, however, mahogany became important later where it was not until the 1960s that it was first exported from Brazil. It has since become a driving force behind the expansion of the Amazon logging industry in both Bolivia and Brazil.

As the two most important exporters of mahogany to the U. S. one might argue that the markets of mahogany from Bolivia and Brazil must be intertwined. In Chapter 4, the results suggest that the production of sawnwood in Brazil has an elastic impact on the supply of Bolivian mahogany. In addition, since there has been a dearth of trade studies for mahogany, the research presented in this chapter begins the process of developing trade models for mahogany. The objective of this chapter is to use the well-established method of cointegration to determine whether the mahogany market from Bolivia and Brazil is perfectly arbitrated or whether there are aspects of the production that cause the price of this, ostensibly homogeneous, product to demonstrate explicit long run differences. To do this, we test for the law of one price, which states that the export price of homogeneous, or well-defined, commodity should be the same, regardless of

destination, and that import prices of that product should all be the same, regardless of origin. To begin, however, this chapter first presents a brief description of the trade of mahogany sawn wood into the U. S., in which the physical characteristics of American mahogany are reviewed and the descriptive trade statistics from 1974 to the 2000 are presented.

American Mahogany (*Swietenia macrophylla* King)

Known as Cuban or Spanish mahogany, the first exports of *Swietenia mahoganii* Jacq. from the western hemisphere began in the late 16th century from countries such as Belize, and Cuba. Currently, the commercial mahogany supplies are from stands of *Swietenia macrophylla* King—family Meliaceae—that has a range stretching from southern Mexico, down the Atlantic coast of Central America, and on into Colombia, Peru, Bolivia, and Brazil. Trees of the *S. macrophylla* species can reach heights upwards of 45 meters with a diameter of between 1.2 and 1.8 meters. Plantation trees do not reach the same height as those grown in stands of natural forest, but can reach up to 30 meters (Walker 1989).

Although a tropical hardwood, at an average of 540 kg/M³, mahogany is considered a medium weight wood. This is easily understood when compared to the weights of some other tropical hardwood such as Purpleheart (*Peltogyne* spp.) At 860 kg/M³, and Lignum vitae (*Guaiacum* spp.) At 1230 kg/M³. Mahogany can be air or kiln dried without warping or checking, but may incur longitudinal shrinkage (Altamirano and Rico 1992). The wood goes primarily to high value cabinets and furniture, interior and exterior joinery, and boat building. Most of the U. S. imports of mahogany go to North Carolina, which has an active furniture and cabinet manufacturing industry.

Classification of U. S. Mahogany Imports

Mahogany is imported by the U. S. and Europe. In Europe the most important market for mahogany is the United Kingdom. The U. S. commands approximately 60 percent of the total mahogany sawn wood market (ITTO-MIS 2001). In the U. S. the mahogany sawn wood is destined primarily to the furniture manufacturers of North Carolina.

Imports of sawn wood mahogany are registered in two sections of the Harmonized Tariff Schedule of the United States. Mahogany sawnwood-rough is registered as 4407240025, and mahogany sawnwood-nesoi (not elsewhere specified or included) is registered as 4407240030. This numbering has been constant since 1996. Prior to 1996 (i.e., between 1989 and 1996) the relevant numbers were 4407230025, and 4407230030, respectively. The descriptive heading, nesoi, is for mahogany sawn wood that has been worked or dressed, but does not include flooring, siding, or moldings. These are the descriptions given for the two sections prior to 1989, when they were reported in the Schedule A, SITC based classification of commodities imported into the United States. This is based on the Standard International Trade Classification, Revision 2, effective with statistics as far back as 1978. Prior to 1978, the data is based on the former SITC values. For which mahogany, is listed as 2343020, 2433220. The numbering for the Schedule A is basically the same as the SITC. The report for general imports and imports for consumption data is compiled by the Bureau of the Census. Between 1978 and 1989 mahogany rough was listed as 2483125 lumber, mahogany, rough, and 2483222, lumber, mahogany, dressed or worked, excluding flooring, siding, and molding. Prior to 1978, mahogany rough was listed as 2343020 lumber, mahogany, rough, and 2433220, lumber, mahogany, dressed or worked, excluding flooring, siding, and mauling.

Origins and Trends of Mahogany Imports

Without doubt, the most important exporter of mahogany to the U. S. is Brazil, which has maintained an average of around 54 percent of the total imports throughout the period 1974-2000. A distant second is Bolivia with approximately 24 percent. After these two countries, there is a very significant drop in mahogany imports with Peru holding 5 percent of the market, Asia 5 percent, and Guatemala approximately 3 percent. Mahogany from Asia is principally from plantations. The largest mahogany exporter from Africa¹, Ghana, is the next most prolific exporter to the U. S. with an average of just over 2 percent of the market since 1974. The mahogany from Chile is likely to have originated in Bolivia, as Chile does not actually produce mahogany. The same is likely for the mahogany from Argentina. The category of other contains a mix of producers and transit countries, and it is quite difficult to differentiate by origin except that some comes through Canada and Europe. For transit country exports to the U. S., it could be argued that the producers' percentages would be quite similar to those that arrive directly from the producing nations. The results presented in Table 4.1 through 4.3 are clearly annual averages and do not capture individual annual changes or changes between regions and nations.

In Figures 4.2 and 4.3 mahogany import volumes from Brazil and Bolivia are graphed. There are clear volume peaks and troughs. In Brazil the most dramatic change takes place in the late 1980s. This peak coincides with the development of new highways in the mahogany region of Brazil—in Para, Mato Grosso, Rondonia, and Acre,

¹ The title of African mahogany subsumes all of the *Khaya* spp.—*Khaya ivorensis*, *Khaya anthotheca*, *Khaya nyasica*, and *Khaya senegalensis*, of Africa, family Meliaceae. The majority of the trade is in *Khaya ivorensis* A. Chev, and *Khaya senegalensis* which grow in Coastal West Africa.

Table 4.1 Historical Averages for Mahogany Exports to the U. S. from Selected Countries

Country	M3/year ^a	Percent
Brazil	65,837	53.84
Bolivia	28,977	23.70
Peru	6,581	5.38
Asia	5,743	4.70
Guatemala	3,577	2.93
Ghana	2,750	2.25
Chile	1,827	1.49
Other	1,826	1.49
Belize	1,090	0.89
Ivory Coast	1,076	0.88
Nicaragua	924	0.76
Honduras	626	0.51
Congo	397	0.32
Cameroon	386	0.32
Mexico	333	0.27
South Africa	125	0.10
Nigeria	107	0.09
Argentina	96	0.08

^a average cubic meters per year from 1974-2000

and of the period when land clearing was actively promoted by the Brazilian government. The Bolivian data shows moderate exports during the 1970s, and then a trough during the early 1980s. This trough coincides with the period of economic instability and hyperinflation that plagued Bolivia from 1980-1985. After that period the exports from Bolivian appear to have a trend of dramatic highs followed by dramatic lows. The can be explained by a variety of factors which include, rainfall, exchange rates, new legislation and other issues as shown in Chapter 3. Of interest is the difference in the values between Figure 3.1 and 4.2. The total exports of mahogany (Figure 3.1) are shown to be less than the mahogany exports to the U.S. (Figure 4.2). This can probably be explained by poor reporting in the Bolivian data. The data in Chapter 3 was collected in Bolivia

from Bolivian sources and it is widely accepted that there is a problem in the reporting of export data. The U.S. import data was collected later, after the model used in Chapter 3 had already been published, and so the model was not updated.

Table 4.2 Average Annual Price (\$/M3) for Mahogany Imports from Aggregated Regions (Adjusted 1996=100)

Year	Africa	Central America	South America	Asia	Other	Avg. price
1974	379	283	290		336	322
1975	327	352	310		198	297
1976	334	591	290		378	398
1977	343	258	249	221	211	257
1978	172	256	216	327	225	239
1979	165	211	188	411	227	240
1980	235	172	296		277	245
1981	416	392	339		280	357
1982	166	372	375	205	324	289
1983	348	293	275	107	240	253
1984	352	413	297	254	283	320
1985	265	314	251	176	280	257
1986	152	280	231	210	284	231
1987	314	388	240	355	306	321
1988	403	174	339	355	318	318
1989	334	281	279	235	371	300
1990	511	282	392	379	413	395
1991	407	396	450	388	675	463
1992	389	338	383	313	210	326
1993	243	202	337	335	157	255
1994	268	240	366	352	381	321
1995	373	294	402	399	458	385
1996	319	334	416	383	519	394
1997	256	250	339	332	414	318
1998	303	334	480	332	459	381
1999	317	216	447	1003	182	433
2000	356	378	529	273	1345	576
Avg. price	313	307	334	334	361	329

Table 4.3 Average Annual Volume (M3) Imports from Aggregated Regions and Total Annual Imports of Mahogany into the U. S.

Year	Africa	Central America	South America	Asia	Other	Avg. Volume
1974	13,915	6,608	45,410	410	642	66,986
1975	5,116	8,309	34,495	24	1,665	49,608
1976	5,321	3,717	32,736	0	1,325	43,099
1977	2,384	2,422	49,019	175	2,217	56,217
1978	6,314	2,278	55,210	210	1,517	65,528
1979	4,618	733	62,833	158	1,750	70,092
1980	1,479	1,889	93,059	0	2,392	98,818
1981	1,309	1,097	104,080	0	1,377	107,863
1982	1,042	960	59,448	215	1,509	63,175
1983	347	2,179	92,021	248	1,679	96,474
1984	1,257	1,193	106,910	196	2,508	112,065
1985	1,179	3,210	130,455	972	6,969	142,785
1986	6,417	4,877	139,250	693	5,948	157,187
1987	12,866	21,663	313,910	1,502	4,276	354,217
1988	3,365	13,486	126,090	2,477	4,705	150,122
1989	2,124	10,601	175,406	1,519	449	190,099
1990	2,554	6,117	85,589	1,094	313	95,667
1991	2,055	5,811	100,761	3,041	35	111,703
1992	733	5,564	89,966	1,631	55	97,949
1993	765	5,449	86,574	49,865	100	142,753
1994	1,275	7,207	139,029	82,442	3,534	233,487
1995	1,789	17,108	150,123	2,155	885	172,060
1996	10,944	11,312	92,766	2,555	1,053	118,630
1997	16,795	15,052	176,296	2,766	357	211,266
1998	10,459	5,803	90,377	51	1,705	108,395
1999	6,293	7,125	84,933	150	341	98,842
2000	8,006	5,078	72,845	502	2	86,433
Yearly avg.	4,841	6,550	103,318	5,743	1,826	122,279
Total	130,720	176,850	2,789,593	155,050	49,308	3,301,521
Percent	4%	5%	84%	5%	1%	100%

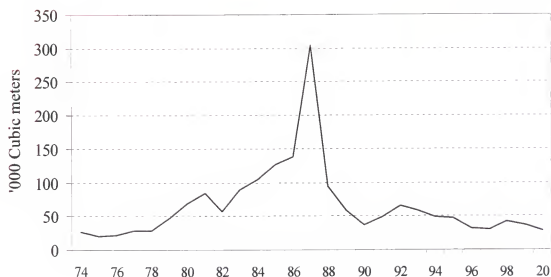


Figure 4.1 Mahogany Imports from Brazil, 1974-2000

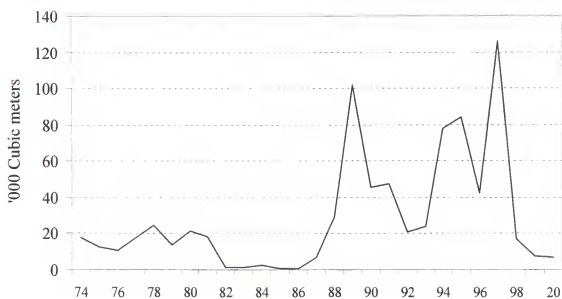


Figure 4.2 Mahogany Imports from Bolivia, 1974-2000

Literature Review, and Testing of the Law of One Price

This chapter presents some of the econometric issues surrounding the estimation of the LOP and its implication for the choice of forest products trade models. First, a discussion of stationarity in time series variables and a review of cointegration and the law of one price. Finally, the LOP is tested for mahogany imports from Bolivia and Brazil.

Times Series and Stationary Versus Nonstationary Data

Times series data is thought to be generated in a stochastic process, or to be random, over time. If this holds true the data is said to be stationary. If it does not hold, and the data is generated in a nonrandom fashion, or in a trend, the data is said to be nonstationary. Thus, the data is said to be stationary if its mean and variance are unchanged over time, while the covariance between two periods depends on the interval between the two periods, and not the time at which the covariance is considered. A stochastic process Y_t is said to be stationary if the following hold true:

$$\begin{array}{ll} \text{mean:} & E(Y_t) = \mu \text{ (constant)} \\ \text{variance:} & \text{Var}(Y_t) = \sigma^2 \text{ (constant)} \\ \text{covariance:} & \text{Cov}(Y_t, Y_{t+j}) = \sigma_j \end{array}$$

Thus, a stationary series has a definite mean and there is a tendency for the data to return to that mean, whereas a nonstationary series will wander from the original mean.

Stationary series are erratic, whereas nonstationary series exhibit trends. The variance in a stationary series is constant, and its autocorrelations will tend to decrease over time; the variance of a nonstationary series will tend to grow, and its autocorrelations tend to one.

In addition, shocks are transitory in stationary series and permanent in nonstationary

series. Nonstationary data can result in concern over the use of the conventional hypothesis testing methods, such as the t, F, and chi-squared tests. In addition, regressions using nonstationary variables can result in spurious regression results that are principally a result of common trends rather than any true correlation. In the case of spurious regressions the results will usually have significant t statistics and a high R^2 value but a low Durbin-Watson value.

A common test for stationarity in a series is known as the unit root. To explain, consider the following model

$$Y_t = \beta Y_{t-1} + \epsilon_t$$

where ϵ_t is the error term, and follows the assumptions of zero mean, constant variance, and no autocorrelation. If the coefficient β is found to be equal to one, then the time series Y_t is said to have a unit root. A time series with a unit root is described as a random walk, and is nonstationary. Furthermore, the equation can be expressed as

$$\Delta Y_t = (\beta - 1)Y_{t-1} + \epsilon_t$$

or

$$\Delta Y_t = \gamma Y_{t-1} + \epsilon_t$$

where $\gamma = (\beta - 1)$ and $\Delta Y_t = Y_t - Y_{t-1}$ (the first difference). The null hypothesis to test for the presence of a unit root in equation XX is that of testing $\gamma = 0$. And, if $\gamma = 0$, then we can rewrite the equation as

$$\Delta Y_t = Y_t - Y_{t-1} = \epsilon_t$$

where ΔY_t , the first difference, is said to be stationary if ϵ_t holds all the correct properties (i.e., is random). Thus, a nonstationary data series can be transformed into a stationary series by taking the difference. If the transformation to stationary take place after

differencing only once, the series is said to be integrated of order one, denoted $I(1)$. If second differences must be used before the series can be made stationary, then the series is described and integrated of order two, $I(2)$. A second difference is the first difference of the first difference, that is,

$$\Delta\Delta Y_t = (Y_t - Y_{t-1}) - (Y_{t-1} - Y_{t-2}) = Y_t - 2Y_{t-1} + Y_{t-2}$$

Note that a stationary series is said to be integrated of order zero, $I(0)$.

The common test for a unit root in a time series was developed by Dickey and Fuller (1979) and is basically that of an OLS regression of $Y_t - Y_{t-1}$ on the lagged variable Y_{t-1} with or without a time trend and a constant, i.e.,

$$\Delta Y_t = \beta Y_{t-1} + \epsilon_t$$

$$\Delta Y_t = \beta_0 + \beta Y_{t-1} + \epsilon_t$$

$$\Delta Y_t = \beta_0 + \beta Y_{t-1} + \beta_1 T + \epsilon_t$$

where β_0 is the constant (intercept) and T is the time trend. Under the null of the presence of a unit root the coefficients do not follow a t -distribution and special critical t -values are needed. The Dickey-Fuller statistic is calculated as the ratio of β to its standard error.

And the test is conducted under the null hypothesis of the presence of a unit root. The critical values differ according to the chosen form of the regression and have been tabulated for each case. The Augmented Dickey-Fuller (ADF) can be used in cases where the error term, ϵ_t , is autocorrelated and appears as follows:

$$\Delta Y_t = \beta_0 + \beta Y_{t-1} + \beta_1 T + \sum_{k=1}^m \beta_k \Delta Y_{t-k} + \epsilon_t$$

where

$$\sum_{k=1}^m \beta_k \Delta Y_{t-k}$$

is the sum of the lagged difference terms. The number of lagged difference terms must be sufficient to ensure that the error term is independent. The same special critical t-values can be used as in the regular Dickey-Fuller (DF) test.

Cointegration

The essence of cointegration is that two variables share a common trend. These series are said to be cointegrated if a linear combination of them is stationary, or $I(0)$, even if, on their own, they are each $I(1)$, or nonstationary. Specifically, if we rewrite

$$Y_t = \beta_0 + \beta_1 X_t + \epsilon_t$$

as

$$\epsilon_t = Y_t - \beta_0 - \beta_1 X_t$$

and then find that ϵ_t is $I(0)$, or stationary, then it can be said that the two variables Y_t and X_t are cointegrated. To test whether the residuals from this regression are indeed $I(0)$, we apply the DF or ADF to the residuals, subjecting them to the unit root test:

$$\Delta \hat{\epsilon}_t = \beta \hat{\epsilon}_{t-1} + v_t$$

This test is known as the Engle-Granger test since the significant values are different for those in the original DF test and were originally calculated by Engle and Granger (1987). There is also an equivalent Augmented Engle-Granger test. If in this case the critical value for β is significant, then the error, ϵ_t , is said to not have a unit root (i.e. it is stationary), and the variables Y_t and X_t are said to be cointegrated. Thus, they exhibit a long run equilibrium.

The Law of One Price (LOP)

The law of one price states that the export price of homogeneous, or well-defined, commodity should be the same, regardless of destination, and that import prices of that

product should all be the same, regardless of origin (Jung and Doroodian 1994; Hänninen 1998). This denotes perfect market arbitrage. To hold, this law implies cointegration of prices (Uri and Boyd 1990; Buongiorno and Uusivuori 1992; Prestemon and Holmes 2000). The law signifies that in equilibrium, $P_{it} = P_{jt}$, and can be written as

$$P_{it} = \delta(P_{jt})^{b_1}$$

Converting to an equation which is linear in the parameters by taking the logarithms, and adding an error term we get (Hänninen 1998)

$$\ln P_{it} = b_0 + b_1 \ln P_{jt} + u_{kit}$$

where, for example, P_{it} and P_{jt} are the import prices from two different countries into the U. S. in a given time period. The logarithm labels ($\ln$) are dropped from here on for simplicity of description. For the law of one price to hold strongly, b_0 must equal zero and b_1 must equal one. And the error term must exhibit all the correct properties (i.e., distributed identically and independently). A weaker example of the law of one price holding would be considered when, the coefficients are close, but not exactly the required levels (i.e., $b_0 \neq 0$ and $b_1 \neq 1$). Two problems present themselves if an OLS regression is run on the price series in the equation to estimate the coefficients. First is that the price may be determined simultaneously and may thus be correlated to the error term so using OLS would lead to bias and inconsistent estimates; and secondly, price series such as these are generally nonstationary (Buongiorno and Uusivuori 1992) and would result a spurious regression with a high R^2 , a low Durbin-Watson statistic, and exaggerated t-statistics. The solution to this problem lies in the use of the concept and practice of cointegration.

Cointegration implies that even though both price series P_{kt} and P_{jt} are individually $I(1)$, their difference should be $I(0)$. Therefore, assuming the strong law of one price holds, and b_0 equals zero and b_1 equals one, the equation can be rewritten as

$$u_{kjt} = P_{kt} - P_{jt}$$

with equilibrium attained when $P_{kt} = P_{jt}$, with u_{kjt} as the equilibrium error. If the prices are cointegrated, u_{kjt} will not have a unit root because it will demonstrate the classical properties. If the prices are not cointegrated, the error term will stay to one side of the origin for extended periods. Therefore, the law of one price can be measured, for two price series, by examining their degree of cointegration. If they are cointegrated, the law is said to hold. The Engle and Granger methodology (1987) for testing cointegration of two price series is that they must first each be tested for unit roots, and then the differences of the prices must be tested for a unit root. If the differences exhibit no unit root, then the prices are said to be cointegrated, and the law of one price holds. For example, each series must first be tested for unit roots using Dickey-Fuller method (1979) as described above and will result in the following equation

$$\Delta P_t = b_0 + b_1 P_{t-1} + \sum_{k=1}^m b_k \Delta P_{t-k} + e_t$$

if the coefficient b_1 is not significantly different from zero, then the series is said to have a unit root, $I(1)$, remembering that the t-statistic for hypothesis testing are those developed specifically for the DF test. If the series have unit roots, the differences between two series can be tested for unit roots. Again using the DF test, but this time on the first difference of the two series

$$\Delta u_{kjt} = b_0 + b_1 u_{kjt-1} + \sum_{k=1}^m b_k \Delta u_{kjt-k} + v_t$$

where a significant b_1 now indicates no unit root, and a stationary first difference of the two series, cointegration of the two series, and acceptance of the strong law of one price.

Application of the LOP and Why it May, or May not, Hold

The LOP is one of the most tested laws in economics today. It is an important part of much international trade literature and modeling. For example, in spatial equilibrium trade models, the objective is the maximization of importer and exporter surplus in all countries (Samuelson 1952, Buongiorno and Uusivuori 1992) and the LOP is assumed to hold for all commodities. This type of model has been used in a variety of formats in modeling the trade of forest products (Adams and Haynes 1980, Boyd 1983, Adams 1985, Boyd and Krutilla 1987, Vincent 1989). Market share models, on the other hand, assume that commodities are distinguished by country of origin, and thus that the LOP does not hold between exporters (i.e., Armington 1969). The test for the LOP has been done for many commodities and there are several results which suggest that it does not hold (Buongiorno and Uusivuori 1992). Table 4.4 presents selected studies and their results as to whether the LOP holds.

In a review of the law of one price in international trade, Miljkovic (1999) suggests several reasons why the LOP may not hold. These are presented as (1) pricing to market, which is a form of imperfect competition in which exporters price discriminate across destination markets. This is possible because countries have different export demand elasticities which provides the incentive for individual pricing to individual

Table 4.4 Review of selected studies of the LOP

Author and date	Commodities in question	Does LOP Hold?
Officer, 1970	Various diss-aggregated commodities	No
Isard, 1977	German and U. S. commodities, including paper	No
Richardson, 1978	Various commodities	No
Ardeni, 1989	Agricultural and metal commodities from Australia, Britain, Canada and U. S.	No
Knetter, 1989	U. S. and German commodities	No
Goodwin, Greenes and Wohlenant, 1990	Oilseed, wheat, corn and sorghum between the U. S., Japan and Rotterdam	Yes
Baffes 1991	Wheat, tea, beef, sugar, wool, zinc and tin between U. S. , Canada, Australia and U. K.	Yes
Pick and Park, 1991	U. S. exports of corn, cotton and soybean	Yes
Goodwin, 1992	Wheat (after accounting for transportation costs)	Yes
Buongiorno and Uusivuori, 1992	U. S. exports of pulp and paper	Yes
Zanias, 1993	Potatoes, soft wheat, milk, pig carcasses in EU	Both
Jung and Doroodian, 1994	Regional markets for softwood lumber	Yes
Hänninen, 1996	U. K. soft sawnwood imports	No
Bierlen, Wailes and Cramer, 1998	MERCOSUR rice markets	Yes
Mohanty, Peterson, Wesley, and Smith, 1998	Wheat, wool, sugar, tea, zinc between Australia, Canada, U. S. and U. K.	Yes

markets; (2) exchange rate risks and choice of currency denomination; and (3) geographical separation of markets, including transportation costs, tariffs and other institutional factors. As mentioned above, one of the reasons for the testing for the LOP is for its use in trade models. The following section reviews several trade models in forest products that have used an assumption of product differentiation by origin, and implicitly assume that the LOP does not hold.

Testing the LOP for Mahogany Imports to the U. S. from Bolivia and Brazil

In the present study, the law of one price for mahogany sawn wood imports to the U. S. is tested using the concept of cointegration for nonstationary time series. In this case we test the cointegration, or linear combination, of two price series—mahogany prices from Bolivia and Brazil. Since 1974, these two countries have controlled an average of 78 percent of the mahogany trade into the U. S., and it is therefore interesting to see whether the LOP holds, implying homogeneous products. Or if it does not hold—implying imperfect market arbitrage or products differentiated by country of origin.

Data

In this section, prices for mahogany rough are used to analyze the LOP. Prices are described by the CIF value divided by the import volume. The prices are quarterly, not seasonally adjusted obtained from the U. S. Bureau of Labor Statistics. In this study we look at two different time periods, the first from 1974-2000 and the second from 1992-2000. We examine both of these because of gaps in the data. In quarters where no transactions took place, it is not possible to determine a price. This occurred ten times in the Bolivian series. In addition, there were two years, or eight prices, that were diss-

aggregated from annual volumes and values for both series. In all, this type of aggregation—filling in missing prices—will tend to make the series more stationary.

Figure 4.3 shows both price series, unadjusted, for 1974 to 2000. For a more clear picture of the individual series, Figures 4.4 and 4.5 show the series for Bolivia and Brazil separately. It appears from the graphs that these series are nonstationary.

Figure 4.6 shows a linear combination of the series (Brazil prices minus Bolivian prices) for the unadjusted series. As mentioned earlier if the error term (linear combination) has a unit root, the prices are not cointegrated. In this case, when graphed, the error will stay to one side of the origin for extended periods. Looking at Figure 4.6 one would expect the prices to not be cointegrated.

The first runs of the model were done with both adjusted and unadjusted prices, but, when the error terms for adjusted and unadjusted prices were graphed together, they had the same trends. Since we are testing whether this trend has a unit root, it is only necessary to use the unadjusted prices.

In addition the models were run using monthly data as well as quarterly. This is to examine whether there is an arbitrage difference between monthly and quarterly data. In this exercise, one would expect that the data would tend toward arbitrage as the data becomes more aggregated—as the data is more aggregated the LOP is more likely to hold.

Methodology

In this exercise, the LOP is tested for mahogany imports to the U. S. from Bolivia and Brazil. These tests first require that the series have unit roots. The series were tested for unit roots using Dickey-Fuller tests. Secondly, those series that had unit roots were

tested for the LOP. For this test, the Engle-Granger cointegration tests were used. A concern in this type of test is that one of the variables must be chosen as the dependant variable. To overcome this problem the results are presented with both series as dependant variables in turn.

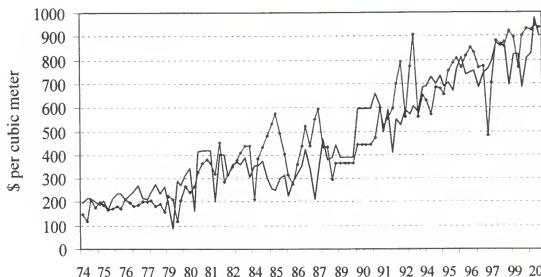


Figure 4.3 Mahogany Prices from Brazil and Bolivia, 1974-2000 (Unadjusted)-
Bolivia with Marker

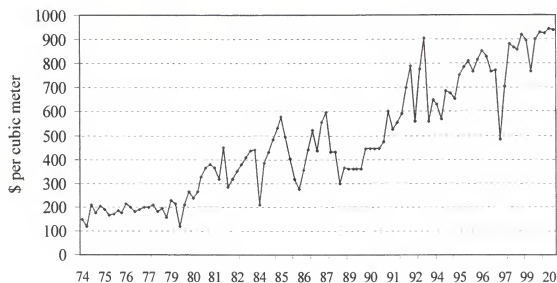


Figure 4.4 Bolivian Mahogany Prices, 1974-2000 (per M3) Unadjusted

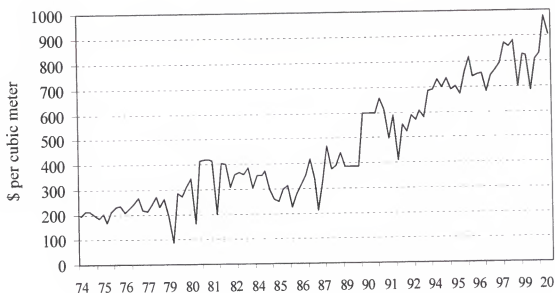


Figure 4.5 Brazilian Mahogany Prices, 1974-2000 (per M3) Unadjusted



Figure 4.6 Mahogany Price Difference Between Brazil and Bolivia
(Brazilian minus Bolivian Price)

Cointegration implies that even though both price series P_{kt} and P_{jt} are individually $I(1)$, their difference should be $I(0)$. The law of one price can be measured, for two price series, by examining their degree of co-integration. If they are cointegrated, the law is said to hold. The Engle and Granger methodology (1987) for testing cointegration of two price series is that they must first each be tested for unit roots, and then the differences of the prices must be tested for a unit root. If the differences exhibit no unit root, then the prices are said to be cointegrated, and the law of one price holds. A more detailed description of these two tests is given above.

Results

The results that the price series had unit roots is shown in Table 4.4 through 4.7. It shows the estimated coefficient, the p value, and the optimal lag length obtained by the Akaike criterion. The tests suggest that the hypothesis of the presence of a unit root cannot be rejected, at the 5 percent level, between Bolivia and Brazil. Therefore the prices are not cointegrated and the LOP does not hold.

In Tables 4.4 and 4.5 the results from the series from 1974 to 2000 are presented. In table 4.4 the null hypothesis of a unit root can be rejected for the Bolivian series, at the 5 percent confidence level. ($P=0.032$). Furthermore, the Brazilian series, with a p value of 0.53, only just passes the confidence test. This result may reflect the aggregation problems in the longer price series. The Engle-Granger results should be discounted in this case because it is a prerequisite that both series have the same unit root. Series with different unit roots, however, as in this case cannot be cointegrated and therefore it would suggest that the LOP does not hold.

Table 4.4 DF Results for Unit Roots for Bolivia and Brazil Mahogany Prices- 1974-2000

Variable	Test statistic	P-value	Lags
Bolivia	-3.58	0.032	2
Brazil	-2.13	0.53*	6

* Represents the presence of a unit root

Table 4.5 EG Results for Testing Cointegration of Mahogany Prices Between Bolivia and Brazil- 1974-2000

Dependant variable	Test statistic	P-value	Lags
Bolivia	-3.61	0.077**	5
Brazil	-3.05	0.24**	3

** Implies a noncointegrated pair of price series (LOP does not hold)

In tables 4.6 and 4.7 the results for the shorter data series are presented. In this case there were no missing data pints, and the results show clearly that the series are not cointegrated. In table 4.6, the p values of 0.29 and 0.093 for Bolivia and Brazil, respectively, do not allow us to reject the null hypothesis of a unit root. In table 4.7 the Engle-Granger tests suggest ($p=0.39$ and 0.24) no cointegration of the price series. These results allow us to suggest that the LOP does not hold for U. S. imports of mahogany sawnwood from Bolivia and Brazil.

Table 4.6 DF Results for Unit Roots for Bolivia and Brazil Mahogany Prices- 1992-2000

Variable	Test statistic	P-value	Lags
Bolivia	-2.57	0.29*	2
Brazil	-3.16	0.093*	7

* Represents the presence of a unit root

Table 4.7 EG Results for Testing Cointegration of Mahogany Prices Between Bolivia and Brazil- 1992-2000

Dependant variable	Test statistic	P-value	Lags
Bolivia	-2.74	0.39**	2
Brazil	-3.06	0.24**	2

** Implies a non-cointegrated pair of price series (LOP does not hold)

The models were then run using monthly data from 1992 to 2000. For the 1974-2000 series there were many points where there was no data, simply because of a lack of transactions, and so only the period from 1992 to 2000 was used. The results for this run are inconclusive. Indeed, the results suggest that both of the series are stationary.

Table 4.8 DF Results for Unit Roots for Bolivia and Brazil Mahogany Prices-Monthly,1992-2000

Variable	Test statistic	P-value	Lags
Bolivia	-5.95	0.00000275	2
Brazil	-4.95	0.000250	2

The results show no presence of a unit root in the either data series. This implies that the monthly data is stationary and therefore not suitable for cointegration testing. The result of stationarity in this data is contrary to expectations, and at this time difficult to explain. One would expect that monthly data would show more volatility than quarterly data, and therefore exhibit the presence of a unit root.

Conclusion

In this chapter, the law of one price was tested for the imports of mahogany sawnwood from Bolivia and Brazil-the two sources which together comprise 78 percent

of total imports. Dickey-Fuller tests were used to establish presence of a unit root (nonstationary) in the two series, and then the Engle-Granger tests were used to establish whether the series were cointegrated.

The conclusion to be drawn from this results presented in this chapter is that the LOP does not hold between Bolivian and Brazilian mahogany sawnwood. It is assumed that primary commodities, such as timber, obey a perfect arbitrage rule and thus the price for these products should be the same. Assuming a homogeneous product it can be said that arbitrage is not working in this market and there are long run price differences. Reasons for the price discrimination between the two suppliers may be those mentioned above: (1) pricing to market, which is a form of imperfect competition in which exporters price discriminate across destination markets. This is possible because countries have different export demand elasticities that provide the incentive for individual pricing to individual markets; (2) exchange rate risks, incomplete pass-through, and choice of currency denomination; and (3) geographical separation of markets, including transportation costs, tariffs and other institutional factors. (4) Estimation difficulties—it is argued that if transportation or other underlying costs are non-stationary then the cointegration of prices is unlikely (McNew and Fackler 1997).

In addition, because non-stationary data does not tend towards a mean, price shocks are permanent (Prestemon and Holmes 2000). That is to say that a change or deviation during one period in one series, perhaps due to a new road decreasing transportation costs, will cause a permanent deviation in the series and discourage cointegration of the two price series. If the prices series are stationary, however, then the prices tend towards a mean and the price shock is temporary. In the case of Bolivia and

Brazilian mahogany, the series are non-stationary, thus the price shocks in either country can cause, or encourage, permanent differences between the two series.

On the other hand, with a result of no LOP we can assume that these two products are differentiated in the market with individual supply and demand equations. Therefore, because it can be argued that these two products, Bolivian mahogany and Brazilian mahogany, are differentiated in the marketplace, they will need country and product specific policies to control production and sale.

Finally, the findings of noncompetitive markets for mahogany from these two countries justifies the use of Armington-type market trade models which differentiate products by country of origin.

CHAPTER 5 CONCLUSION

This research has been conducted under the umbrella topic of sustainable forestry. This is a broad topic that allows, and indeed encourages, multi-faceted research. The four studies in this dissertation embrace that diversity, looking at very different aspects of land use, the timber trade, and forest policy in Eastern Bolivia.

Chapter 2 used a dynamic linear programming model to examine land use conversion from sustainable forestry to pasture for cattle production. Chapters 3 and 4 provide preliminary insight into the trade of mahogany from Bolivia and into the U. S. These two separate perspectives are linked within the overall issue of forest policy and trade in Eastern Bolivia. The individual nature of these studies requires particular conclusions for each section. This concluding chapter reiterates these conclusions and then attempts to draw some universal conclusions regarding land use, the timber trade, and forest policy for eastern Bolivia.

The simulation results in Chapter 2 clearly indicate that the two regions of the Brazilian shield, Chiquitanía and Guarayos are higher risk areas, and will likely suffer the most conversion from forest to pasture. All of the other regions—the Andean Foothills, Paraguá, and Pando—appear, under current conditions, to be in little risk of major land conversion within the next 20 years; due both to high forest productivity as well as poor cattle production conditions.

Following that result, land conversion subject to changes in net returns to sustainable forestry was examined. The results show that when the annual returns from sustainable forestry production release an initial capital constraint, which subsequently makes capital available to compensate for the costs of land conversion, more land is converted to pasture. As the price of stumpage continues to rise, the stumpage value becomes sufficiently high that the marginal benefit of forestry stops conversion to pasture. But up to that point there are circumstances that policy makers and land use planners must address when increasing marginal returns to forestry can, indeed, exacerbate land conversion to pasture.

The results also imply that forest management costs which include land use planning requirements can drastically affect the level of land conversion - with higher forest management costs increasing land conversion to pasture, all else equal. Finally, these results suggest two points (1) that under conditions of high forest management costs, relative land taxes are not an important determinant of land conversion; and (2) under conditions of low forest management costs, changes in pasture taxes are more effective determinants of land conversion rates than forest taxes.

The policy implications of this work lie in the freedom to vary land taxes and land use requirements to minimize land conversion. At present forest land taxes in Bolivia are set at a national level. This work shows that increased flexibility would encourage sustainable forest production in marginal regions and thus reduce the risk of land conversion to other uses.

Chapter 3 presents a market model that lends some support to the claim that mahogany stocks are declining but also brings into doubt the potential of the new

legislation to control the harvest and export of an individual species such as mahogany. The model suggests that there has been a decline in mahogany exports of four percent per year over the study period. And, because mahogany, where available, is usually the first species extracted from the forest, it is assumed that this decline in exports relates directly to a decline in mahogany inventory. Mahogany has been the primary export species and is potentially an important generator of foreign currency for the Bolivian government, and it is hoped that documentation of this decline in supply will provide impetus for policies that sustain remaining inventory.

The results indicate that controlling the total number of hectares under concession has a less than proportional impact on exports supplies. It would appear that the area based tax mechanism may affect the sector as a whole but is not as effective in controlling the supply of an individual species that is harvested at the frontier. And, unfortunately for the commercial stock of mahogany, this is the current mechanism through which the Bolivian government is managing its forest resource.

The more viable option for controlling mahogany extraction is pricing policy. Indeed, the results show that export supply is sensitive to both export and domestic prices. Without explicit analysis of the domestic market, however, it is not possible to accurately estimate to what degree the total harvest (export supply and internal consumption) is sensitive to variation in export prices. However, because the domestic market is of limited demand and is, in addition, replete with substitute products, it is likely that the total mahogany harvest is very sensitive to export prices.

Therefore, it appears that policies that reduce stumpage values, such as ad valorem or export taxes, may be the best option to sustain the remaining mahogany stocks for the near future until more sustainable forest management practices are adopted.

In Chapter 4 the law of one price was tested for the imports of mahogany sawnwood from Bolivia and Brazil—the two sources which together comprise 78 percent of total imports. The conclusion to be drawn is that the LOP does not hold between Bolivia and Brazil for mahogany sawnwood.

It is usually assumed that primary commodities, such as timber, obey a perfect arbitrage rule. Assuming a homogeneous product, it can be said that arbitrage is not working in this market and there are long run price differences. Or, with a result of no single long term price, we can assume that these two products are differentiated in the market.

The reasons for the price discrimination between the two suppliers may be those mentioned earlier: (1) pricing to market, which is a form of imperfect competition in which exporters price discriminate across destination markets. This is possible because countries have different export demand elasticities that provide the incentive for individual pricing to individual markets; (2) exchange rate risks, incomplete pass-through, and choice of currency denomination; and (3) geographical separation of markets, including transportation costs, tariffs and other institutional factors. (4) Estimation difficulties - it is argued that if transportation or other underlying costs are non-stationary then the cointegration of prices is unlikely (McNew and Fackler 1997)

In addition, because nonstationary data does not tend towards a mean, price shocks are permanent (Prestemon and Holmes 2000). That is to say that a change or

deviation during one period in one series, for example a new road that decreases transportation costs, will cause a permanent deviation in the series and discourage cointegration of the two price series. On the other hand, if the prices series are stationary, then the prices tend towards a mean, and the price shock is temporary. In the case of Bolivia and Brazilian mahogany, the series are non-stationary, thus the price shocks in either country can cause, or encourage, permanent differences between the two series.

Therefore, because it can be argued that these two products, Bolivian mahogany and Brazilian mahogany, have individual supply and demand equations and that policies to control the production and sale of mahogany must be country specific.

Finally, the findings of non-competitive markets for mahogany from these two countries justifies the use of Armington-type market trade models which differentiate products by country of origin.

The overall conclusions that can be drawn from the dissertation can be summarized as:

- (1) The rate of land conversion to pasture will differ between regions and that some flexibility in the land use taxes, to adjust for this difference, is warranted.
- (2) Variations in the, already very low, forestry tax on private lands will not change the extent of land converted to pasture.
- (3) If there is a low forest management cost, increasing the tax on pasture lands can be an effective mechanism to discourage land conversion.
- (4) When the stumpage price is initially low, policies that increase this price will alleviate a capital constraint and can exacerbate land conversion to pasture.
- (5) A sufficiently high stumpage price will, however, eventually allow sustainable forestry to out-compete cattle production and reduce the incentive for land conversion.

- (6) Policies that control the area under concession are not likely to affect the supply of mahogany; a more effective means of controlling mahogany supply would be pricing policies such as export taxes.
- (7) The law of one price does not hold for U. S. mahogany imports from Brazil and Bolivia, which implies that the mahogany is differentiated by country of origin.

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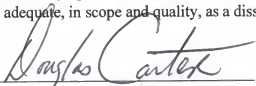
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BIOGRAPHICAL SKETCH

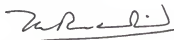
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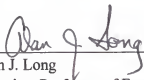
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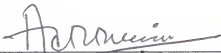
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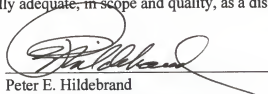
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